Improving Iran's Domestic Energy Basket

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Proefschrift

Ter verkrijging van de graad van doctor
aan de Universiteit van Tilburg,
op gezag van de rector magnificus, prof. dr. F.A. van der Duyn Schouten,
in het openbaar te verdedigen ten overstaan van
een door het college van decanen aangewezen commissie
in de aula van de Universiteit
op vrijdag 5 september 2003 te 10.15 uur

door

Mohammad Reza Moghaddam

Geboren op 22 december 1952
te Teheran

Promotor: prof. dr. ir. J. Ashayeri
Copromotor: dr. ing. W.J.H. van Groenendaal

To My Family

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Mohammad Reza Moghaddam

Tillburg – September 2003

Improving Iran's Domestic Energy Basket

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Chapter 1

Introduction to the Problem

1.1 Introduction

The Islamic Republic of Iran is a country with many problems, especially with its economy. However, for many people outside Iran, its name is associated with three products: pistachio nuts, carpets, and oil. Although the first two products are well known, they contribute only a small fraction to the Iranian economy. Oil comprises the vast bulk of the Iranian economy. Therefore, it is important that Iran uses the latter to the benefit of the economy. On this principle all Iranians agree, but the question is how it can be achieved. Most people in Iran believe that the current policy; that is, making energy available at extremely low prices, is the best way for the Iranian people to benefit from its energy resources. In this study we analyze this popular belief and will reveal alternative policies. Furthermore, since oil is an exhaustible resource, we will show that Iran's current domestic energy policy will lead to an economic disaster in the not so distant future, and that drastic change in Iran's domestic energy policy is required.

This chapter contains a brief introduction to the problem analyzed in this research. Section 1.2 discusses the subject and objective of this research. Section 1.3 discusses the research methods used, and Section 1.4 contains an outline of the contents.

1.2 Research Objectives

The subject of this research is to optimize, or better improve, the longer-term -up to 2020- use of different energy carriers in the Islamic Republic of Iran. Generally speaking the optimal energy basket is the basket that captures the opportunities of international and domestic energy markets, and avoids and/or eliminates threats and constraints faced by the domestic energy sector. At present the level of consumption of different energy carriers as well as the division of consumption over energy carriers in Iran is far from optimal. Due to Iran's extremely low prices of energy carriers, energy is not allocated efficiently.

The Iranian economy depends heavily on crude oil export, which is some 80% of total exports. However, the market share allocated by OPEC limits Iran's oil export. Improving Iran's production capacity could result in a larger market share when renegotiating the shares, but with many of Iran's reserves beyond their production peak a significant increase in production is difficult if not impossible to realize. Therefore, the domestic growth of consumption of all types of energies strongly affects the Iranian economy.

During the years 1988 to 1998[1], Iran's average annual growth rate of final energy consumption has been 6.7%, and at the same time the average annual growth rate of the consumption of refined petroleum products has been 4.2%. If this trend continues, the domestic demand of crude oil will be about three millions barrels per day by the year 2010 (IIES, 1994). On the other hand, crude oil production will, by 2010, be less than 4 million barrels per day. Iran's main reserves have passed their peak production, and reservoir pressures are dropping. Even if the National Iranian Oil Company (NIOC) manages to develop all new fields currently known, production will only be about 3.5-3.8 million barrels per day by 2010 (IIES, 1994).

Figure 1-1 illustrates the various trends. If Iran's domestic energy policy is not changed, there is a fair chance that Iran's domestic consumption requirements will change it from an oil exporting country to an oil importing country somewhere between 2010 and 2020. As a result, the income from oil will be reduced drastically. Even policies to reduce domestic oil consumption, such as the investment in gas production facilities for domestic gas use and for the use of gas in oil and power production will no longer be possible. This will hamper the improvement of oil production in existing fields, as well as the development of new oil fields. Needless to say, that before this happens Iran will face severe economic and social problems.

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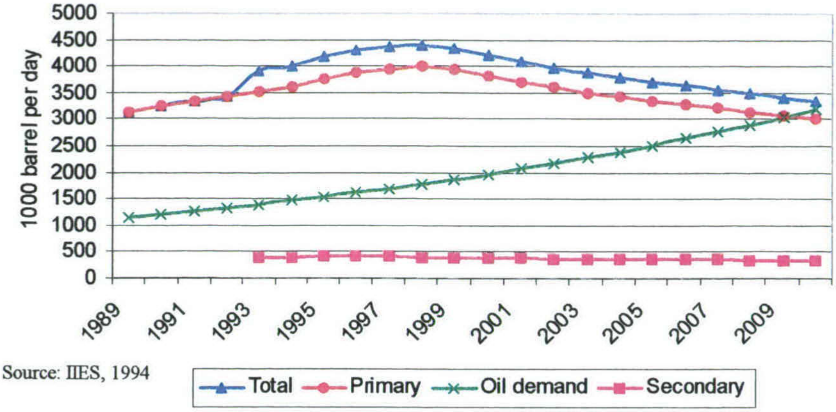
[1] The Iranian calendar year starts on March 21 and ends March 20 the following year. By adding 621 to the Iranian year, we convert it to Gregorian calendar.



Source: IIES, 1994

Figure 1-1. Possible trends of Iranian domestic oil production and consumption

Apart from oil Iran has large associated and non-associated natural gas reserves. These gas reserves are difficult to export. However, gas is produced for usage in oil production. With good domestic energy policy it is possible to (partly) replace the domestic use of oil products by natural gas; this can be achieved in several direct and indirect ways. This policy would postpone the switching point from oil export to oil import, and oil export is possible for a longer period of time, earning money that can be used to improve the non-oil economy (Ministry of Energy, 1999).

In the past, three main factors have contributed to the inefficient and uneconomical energy consumption in Iran. These factors are:

- The energy sector is under the complete control of the government and is managed inefficiently and ineffectively.
- Iran's domestic energy prices are among the lowest in the world and often even below production costs. Domestic energy use is implicitly heavily subsidized.
- The absence of effective non-price energy policies that would mitigate the effect of the low energy prices.

All three factors are important, but the extremely low (subsidized) prices of the energy carriers have caused the high rates of energy growth in households as well as industries. Furthermore, the lack of energy conservation regulations, such as building and construction codes, amplifies the non-optimal use of energy.

Also in the primary energy sector (power and refinery) the current organization of the domestic energy sector leads to severe problems. Because energy prices are low, the sector cannot invest from its own financial resources, but requires government funding and is subject to constant ministerial control. This results in slow and often ineffective decision-making, which culminates into large inefficiencies in the primary energy sector.

Thus, Iran's present energy basket is not optimal, neither from an available energy resource, nor from an effective and efficient use point of view. Therefore, this research aims at

"*identifying the strengths and weaknesses of Iran's domestic energy sector, as well as its opportunities and threats, in order to formulate a domestic energy policy that, better than the current policy (or better the lack thereof), benefits the Iranian economy in the long-term.*"

The research will in particular answer the question of how Iran's energy pricing policy should be adjusted, possibly in combination with energy conservation policies, to improve domestic energy use and Iran's economic performance. It is our intention to base our policy proposals on sound empirical analysis. The reader should, however, be aware of the many political and economic problems Iran faces (and has faced in the past), which complicate such an empirical analysis.

Apart from the complex problem of Iran's domestic energy prices, Iran has two other main policy issues. First, Iran has large quantities of associated and non-associated natural gas that can be produced cheaply, and is easier to use domestically than to export. This policy is already in place and progress has been made. Second, Iran's government sector is large and operates slow. The government exerts tight control over all energy related activities. First steps have been taken towards liberalization and privatization, but these steps are far from adequate to having an overall efficient energy sector.

1.3 Research Methodology

To improve Iran's domestic energy policy we apply a combination of methods. First, we apply strategic planning to identify Iran's threats and opportunities as well as its strengths and weaknesses. These are then used to identify the main strategic issues and to formulate the main policies. Second, an econometric model of Iran's domestic energy sector is formulated. This model is then used to analyze the formulated policy scenarios.

For an organization or firm, the formulation of a strategy is based on surveying the external environment for threats and opportunities, and an internal survey of strengths and weaknesses, taking into account the expectations of stakeholders and the institutional culture of the organization (Hill, 2001). As is shown in Figure 1-2, strategy is created at the intersection of an external appraisal of the threats and opportunities an organization faces in its environment, expressed in terms of key factors for success, and an internal appraisal of the strengths and weaknesses of the organization itself, distilled into a set of distinctive competences. Outside opportunities are to be exploited by inside strengths, while threats are to be avoided and weaknesses circumvented. The values of the leadership as well as the ethics of the society and other aspects of so-called social responsibility are to be taken into consideration, both in the creation of the strategies and in their subsequent evaluation when choosing the "best" strategies. Once a strategy has been chosen, it is translated into policies that can be implemented. In the literature this is know as Strengths and Weaknesses, and Opportunities and Threats or SWOT analysis (Koch, 2000 and 2001; and MindTools, 2003).

According to the above, the strengths and weaknesses, and the opportunities and threats the organization faces must be specified. A strategy will be chosen in such a way that it captures the opportunities and strengths, and reduces the weaknesses as well as the possible effects of threats. The strong and weak points are the result of an internal analysis. These are within the authority of the policy makers and they can influence them. The opportunities and threats are part of the problems environment and cannot be influenced by the policy makers, but merely worked around.

This methodology will be applied to Iran's domestic energy sector. Although SWOT analysis has originally been developed for corporations and their strategic planning, the methodology can also be applied for a region or a country. In each situation, one can identify the internal and external factors needed for a SWOT analysis. This can then be used to complete the analysis as outlined in Figure 1-2.

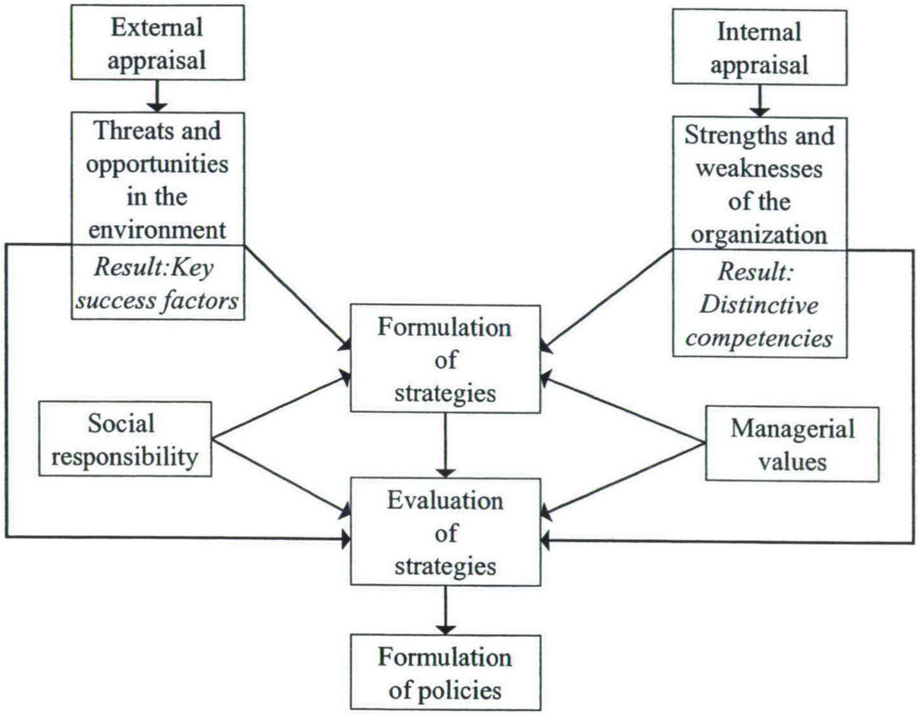


Figure 1-2. Selecting a strategy based on strategic analysis

Once the policies to implement the strategy have been formulated, their viability needs to be tested. For this a quantitative instrument in the form of an econometric model of Iran's s domestic energy market shall be formulated. This instrument should allow us to quantify the effects of the policy and check whether the proposed policies are beneficial to the Iranian economy and the Iranian people.

There are a few restrictions for this research. First, Iran is a member of OPEC and intends to stay within OPEC. We will not analyze what could happen if Iran would leave OPEC. Although an interesting exercise, this research focuses on Iran's domestic energy market. Furthermore, Iran has many political problems, both domestically and internationally. On top of that Iran is located in a part of the world that is known for its many political problems that cannot be resolved easily. When finalizing this study the United States invaded Iraq, and it is unclear what the near future will bring to the Persian Gulf region. We are aware of the many political problems and undoubtedly a war in Iraq will have an effect on Iran -which was linked to Iraq in president's Bush's axis of evil-, but it is beyond our research capabilities to analyze the possible effects of the war.

1.4 Research Structure

The starting point for this research is a description of Iran's current economic situation as well as a brief review of its past since the 1979 Islamic Revolution. This is the subject of Chapter 2. We will show that the current domestic energy policy harms the economy and if the current trends in domestic energy consumption and production continue, Iran will face far more serious economic problems than it already does. This domestic analysis of the strengths and weaknesses of Iran's domestic energy sector, as well as its opportunities and threats, is essential for the formulation of a better domestic energy policy.

Moreover, the Iranian economy is affected by several international factors, such as the policies of oil producing countries, and more in particular OPEC, international oil markets and more general international energy markets, trends in future consumption of energies in the world, energy intensity in developed and developing countries, environmental policies, etc. In the strategic planning methodology, these are called environmental factors that are not under the authority of domestic decision-makers. They may hold threats or opportunities for Iran's domestic energy sector and it is necessary to analyze these threats and opportunities. This is discussed in Chapter 3.

The analyses of Chapter 2 and Chapter 3 are used in Chapter 4 to conduct a complete SWOT analysis and formulate strategies as outlined in Figure 1-2. It explains how the SWOT analysis can be used to analyze Iran's domestic energy sector.

To analyze the potential policies that result from the new domestic energy strategy a suitable model is required. Chapter 5 reviews energy demand models and their usefulness for our research goal. It discusses three main types of models General Equilibrium, Variance Autoregressive models, and traditional Structural or Simultaneous Equation models. We will argue which type is most suitable for our analysis.

In Chapter 6 the actual model is built and tested, and used to simulate a reference scenario up to the year 2020. This reference scenario indicates how the domestic energy sector will develop without a change in policy.

Chapter 7 evaluates the effects of the new domestic energy policies as formulated in Chapter 4 and analysis how these affect economic growth. It will be shown that, contrary to popular belief in Iran, domestic energy price increases have a positive effect on the domestic economy. The effect of increased energy prices is domestic energy conservation, which increases the oil export potential. As we shall show, the income from extra oil exports in combination with the domestic revenues from increased energy prices, allows the Iranian economy to lower inflation and to invest more in economic development.

Chapter 8 contains conclusions and recommendations for further research.

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Chapter 2

Iran's Economy and Domestic Energy Markets

2.1 Introduction

In this chapter the main strengths and weaknesses, as well as opportunities and threats governing Iran's economy are reviewed. Given the subject of this research, in particular the role oil and gas play in Iran's economy will be discussed. Iran's main export commodity is crude oil and Iran is a prominent member of OPEC. Although the OPEC member countries review the production quota at least every six months, a country's production quota does not fluctuate that much. As a member of OPEC, Iran's total crude oil production quota is, for the time being, set at 3.84 million barrel per day (bbl/d), which is, as we will show, close to its production capacity. Changes in quota are used in efforts to stabilize the price of crude oil; OPEC currently aims at a price of oil between 22 and 28 US$ per barrel. Despite these efforts, the price of crude oil shows large fluctuations. In January 1999 the price was less than 10 US$ per barrel, which passed in silence, whereas it was more than 32 US$ in February 2001, leading to strong pleas from the industrialized world to increase production. Because of these swings in international oil prices, Iran's income from oil export is very volatile, and this of course has strong implications for its economy and the planning thereof.

There is one extra complication. The production quota set by OPEC cover domestic demand and export. So a growing domestic demand for oil products reduces the amount of oil available for export. As we shall show, this causes major challenges for Iran's domestic energy policy, since this problem was -and to a large extend still is- insufficiently recognized by the Iranian government. This has led to an unsustainable domestic energy policy that can, as we will show, only be solved through tough policy measures, such as a drastic domestic energy price increase. The question is how to formulate these measures in such a way that the short-term negative economic and social consequences for the Iranian people are minimal.

Already for many years Iran has implicitly subsidized domestic energy use (as it does with many other commodities) through extremely low prices, which are among the lowest in the world. For example, the price of one liter regular unleaded gasoline in Iran in the year 2000 was 4.7 US$-cents, based on the free market exchange rate. This price is extremely low compared to 32.8 US$-cents in the USA, 94.4 US$-cents in Germany, 108 US$-cents in the Netherlands, and 136 US$-cents in Norway in the first quarter of 2000 (IEA, 2000). The prices of other oil products reflect similar differences, as do natural gas and to a lesser extent electricity. The current pricing policy is such that energy use in Iran is implicitly heavily subsidized, since energy is sold below its opportunity value (and on several occasions even below its production cost).

The energy intensities of Iran's economic sub-sectors that resulted from this domestic energy policy are much higher than those in other countries, and have increased rapidly for a long time. Domestic primary energy consumption has grown by a factor 5.6, from 142.4 million barrel of oil equivalent (BOE) in 1974 to 795.1 million BOE in 1998, most of which is met by oil products, whereas the real GDP grew by a factor of 1.6 only, from 10,869 billion Rial to 17,051 billion Rial respectively. This large difference in growth factors, which was not the result of a drastic change in the structure of the economy, illustrates the severity of the domestic energy problem.

Remark: For this research a databank, containing energy and economic data was established in cooperation with the Institute for International Energy Studies (IIES) in Tehran. All data were made consistent and therefore can differ from those published by, for example, the Ministry of Energy in the Energy Balance and the Statistical Yearbook. A brief description of the data available will be given in Section 5.4.

This has resulted in a domestic demand for oil of 1.21 million barrels per day, limiting the oil export potential to 2.51 million barrels per day in 1998. So, implicit energy subsidies are increasing rapidly and at the same time exports earnings are decreasing. As we will show, total implicit energy subsidies have increased, and amounted to more than US$ 14.3 billion in 1997 (which is about 95 percent of the dollar value of oil revenue). This mechanism puts a lot of pressure on Iran's economy and seriously limits its potential for growth.

In this chapter Iran's economic development is reviewed and special attention will be paid to the role of energy in the growth of the economy. Section 2.2 reviews Iran's main economic variables, its economic growth rate, employment, productivity, and population growth, as well as some relevant past policies. Section 2.3 briefly reviews Iran's primary energy reserves, and discusses domestic energy production and consumption. The energy intensities of various economic sectors are discussed in this section also. Section 2.4 discusses the nominal and real domestic prices of energy, border prices, and what this means in terms of implicit energy subsidies. Section 2.5 reviews Iran's domestic energy policy intentions for the future as agreed upon by the Iranian parliament, the Majlis. Since Iran is a member of OPEC, the role of OPEC and its impacts on Iran's economy as well as the quota restrictions are discussed in this section also. Section 2.6 contains conclusions.

2.2 Iran's Main Development Indicators

This section discusses the main indicators that are of importance when describing a country's economy. These comprise demographic indicators, macroeconomic indicators, and for Iran the role of oil and oil income. To understand Iran's strengths and weaknesses, as well as opportunities and threats, it is necessary to discuss all of these issues. In Subsection 2.2.1 population and employment are discussed. Subsection 2.2.2 reviews the role of oil revenue as a share of the total economy government expenditure. Subsection 2.2.3 is concerned with macroeconomic indicators as real gross domestic product, labor productivity, and investment and consumption.

2.2.1 Population and Employment

According to the international population classification, Iran is among the top fifteen of countries in terms of population growth (IMF, 2000). In 2000, the population was 63.9 million people (CBI, 2001), compared to 31.95 million people in 1974. A high population growth rate and a low average age are the two main characteristics of the

Iranian population. Table 2-1 shows the share of young people in Iran's total population between 1974 and 2000.

Between 1974 and 2000 major changes occurred in terms of rural and urban population also. The share of the urban population grew from 45.1% in 1974 (14.4 million) to 64.7% in 2000 (41.4 million). The total annual population growth rate over the period 1974-2000 was 2.7%, but the population growth rate of cities over the same period has been 4.1% annually, whereas in rural areas it was only 1%. This shows that the Iranian economy is changing from a rural economy, based on agricultural products, to an urban economy requiring a larger manufacturing and services sector.

Table 2-1. Iran's population structure

Year	*Total population (Million)*	*Annual growth rate (Percentage)*	*Age group 0-19 (Percentage)*	*Population 15-65 (Percentage)*
1974	31.9	2.7	54.7	51.4
1980	39.3	3.9	55.3	51.6
1985	47.6	3.9	55.8	51.3
1990	54.5	2.5	54.9	51.9
1995	59.2	1.5	51.9	55.0
2000	63.9	1.6	49.4	57.7

Source: Iran Statistical yearbook, Statistical Center of Iran, 1998; and CBI, 2001.

The share of the population at working age (15-65 years) has grown also, from 16.4 million in 1974 to 36.9 million in 2000, an annual growth rate of 3.1%. To provide work for the young urban population, strong economic growth is required. However, as we will show next, the growth of employment opportunities has been much lower, leading to much (hidden) unemployment.

Employment

In 1974, about 8.43 million people were employed, whereas in 2000 this number almost doubled to 15.87 million, an average growth of only 2.4% annually. The major part of employment in the private sector is in small commercial enterprises. Total private sector employment in 2000 was about 68.8% The government sector, with 31.2% in 2000, was by far the largest employer. This indicates a seriously inflated government. The ratio of people employed over economically active people[1] was

1 Economically active people are the people between the ages of 10 to 65, excluding students, housekeepers without pay, and income recipients without work.

83.7% in 2000, which in turn results in an unemployment rate of 16.3% (Central Bank of Iran, 2001). Especially in recent years Iran has experienced a strong increase in the rate of unemployment, in 1996 it was much less 9.1% (CBI, 1997).

Every person with work, on average, has to earn enough to support 4.2 persons. This situation is worse when the hidden unemployment in the inflated governmental sector is taken into account. For an extended discussion of these population issues, see Salehi-Isfahani (2000).

2.2.2 Oil Revenues in Iran's Economy

Iran, as an oil exporting country, is in the group of basic commodity supplying countries. Its national economy strongly depends on the export of crude oil. Therefore, the performance of Iran's total economy is strongly affected by fluctuations in oil income, and given OPEC's quota system these fluctuations are mainly caused by fluctuations in international oil prices. This dependency of oil can be further characterized as follows; also see Table 2-2.

Table 2-2. Importance of oil income in Iran's economy (in percent)

Year	*Share of oil in export income*	*Share of oil income in government budget*	$GVA_{oil\ sector}/GDP$
1974	89.0	86.4	44.4
1980	94.8	61.1	9.4
1985	96.8	39.7	14.1
1990	93.2	53.9	21.2
1995	82.4	64.2	18.1
1996	86.1	57.2	17.5
1998	75.7	30.8	15.6
2000	85.5	59.0*)	13.6

Sources: National Account of Iran, Central Bank Yearly Balance, and Economic Trends, all published by the Central Bank of Iran.
Note: Gross value added (GVA) and GDP in constant 1982 market prices.
*) This includes oil revenue and income form free market oil dollar sales.

The ownership of Iran's oil and gas reserves as well as all related industries is with the government. Since oil is Iran's main export commodity, a large part of the public budget stems directly from oil export. Any unexpected decrease in oil income affects the government budget directly and can result in dramatic problems, as was the case in 1998 when oil prices fell to almost 10 US$/bbl.

Table 2-2 shows that the share of crude oil export in total export income has always been more than 75%, even when oil prices were low, and normally is over 80%. During the period of 1974-2000 dollar oil revenues were on average responsible for more than 86% of Iran's dollar revenues.

In addition, the share of oil income in the government budget is high too. Table 2-2 shows this share strongly fluctuates, which is due to fluctuations in international oil prices. Figure 2-1 shows the trend of the OPEC basket oil price and Iran's revenue from oil export. The figure shows that, with the exception of the years 1980-1982 when Iran faced a lower level of oil production, and as a result oil export, due to the Iraq-Iran war, Iran's oil revenues closely follow the oil prices. The share of oil revenue in the basket of government revenues was 86% in 1974 and more recently about 60%.

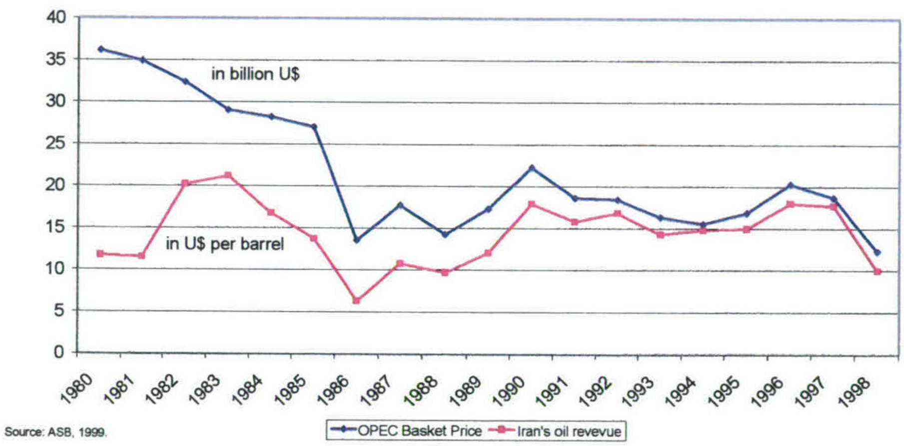

Figure 2-1. OPEC's oil price and Iran's oil revenue

The importance of oil is also reflected by the share of the real gross value added of the oil sector in Iran's total real gross domestic product (GDP), which is on average about 19%; see Table 2-2.

Over 95% of the domestic energy demand is met by the fossil fuels oil and gas, which are transformed by Iran's energy sector into the energy carriers demanded.

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students, housekeepers without pay, and income recipients without work.

Iran's government sector has grown rapidly in the past and all major energy industries are either owned by the state or completely depend on the state. Examples are the National Iranian Oil Company (NIOC), the National Iranian Gas Company (NIGC), the National Iranian Oil Refining, Distributing Company (NIORDC), and National Petrochemical Company (NPC), which are all subsidiaries of the Ministry of Petroleum; also see Section 2.5.

Note that the energy sector is not the only sector dominated by the government; also the insurance industry, iron and steel, and the banking sectors are either owned or completely controlled by the government.

2.2.3 Economic Trends

When discussing the changes in Iran's GDP since 1974, three main periods have to be distinguished. The first period is the period before the Islamic revolution (1974-1979), which was politically unstable time due to social unrest. The second period, 1979-1988, was a very chaotic period, which started with the Islamic revolution in February 1979 and shortly thereafter, in September 1980, Iraq invaded Iran, starting a war that lasted till August 1988 when a ceasefire was agreed upon. The third period started in 1989, when rebuilding Iran was high on the political agenda. To achieve this the Iranian government introduced social-economic five-year plans, which were introduced for the first time in 1989.

The first two periods, for obvious reasons, show large fluctuations in production. The real gross domestic product at constant 1982 market prices (denoted by GDP) first increased from 10,869 billion Rial in 1974 to 13,255 billion in 1977, but then came down sharply to 9,177 billion in 1981; see Figure 2-2.

During the war period Iran's export capacity decreased, whereas its requirements increased. This is illustrated in Figure 2-2 by the fact that GDP is below or only slightly above the sum of consumption, investment, and government expenditure.

However, as a result of the war effort, the reduction in GDP was partly compensated by a considerable growth in 1982 and 1983, and in 1985 it was 11,607 billion Rial again. Thereafter, the real GDP decreased again for two years and was rather constant until 1989. Iran's efforts to increase its GDP during this period were rather constant until 1989. Iran's efforts to increase its GDP during this period were counterbalanced by the destruction of many of its vital industries and the resulting continued reduction in oil incomes.

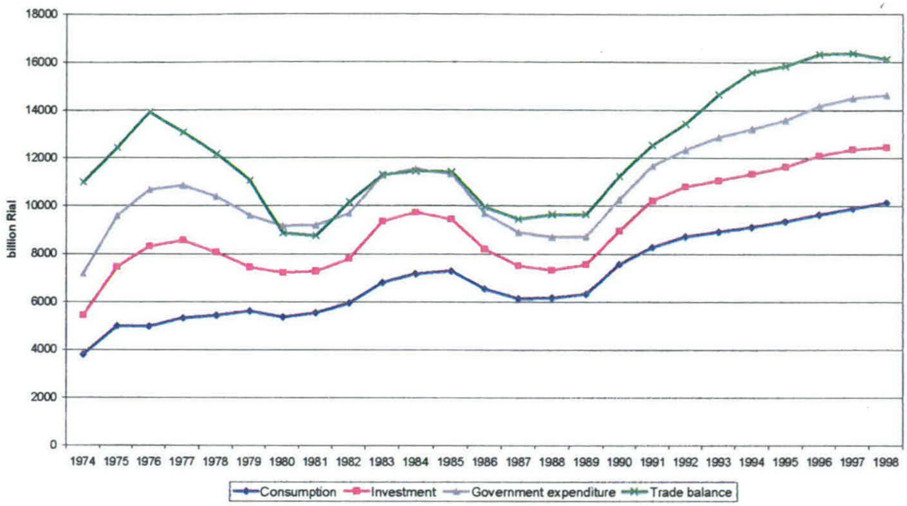

Figure 2-2. GDP and its main components in 1982 market prices

In 1989, one year after the 1988 cease-fire and the start of the reconstruction, real GDP was 11,067 billion Rial. Since then, real GDP has shown a moderate but continued growth; also see Figure 2-2. To coordinate reconstruction, the first five-year plan was developed for the period 1989-1994.

Table 2-3. Labor productivity, and GDP, consumption, and investment per capita in 10^3 Rial

Year	Productivity	GDP	Consumption	Investment
1974	1288.9	340.2	118.7	51.1
1980	983.3	240.8	136.4	47.0
1985	1132.9	256.1	153.2	45.3
1990	973.3	225.9	138.8	25.3
1995	1073.7	258.8	158.1	38.5
2000	1189.9	290.5	171.3	37.9
Growth: 1988-2000	*2.3%*	*2.9%*	*3.0%*	*4.5%*
Growth: 1974-2000	*-0.3%*	*-0.6%*	*1.4%*	*-1.2%*

Source: National Account of Iran, Central Bank Yearly Balance, and Economic trends, published by Iranian Central Bank, various volumes.

The war period also (partly) explains the growth of the government sector, but the main cause of Iran's inflated government is the revolution, in which the "great requisition" and "nationalization" occurred. This was partly because of the economic view of politicians who thought (and many still do) that the government can run the economy, and partly because the war needed extraordinary coordination of all efforts.

Due to the fast population growth and chaotic economic development, the per capita GDP decreased by 0.6% per year, and came down from 340 thousands Rial (5,196 US$) in 1974 to 295 thousands Rial (168 US$) in 2000; see Table 2-3. A reduction of almost 24% in per capita income, based on real Rial values, which is even worse in US$ terms. In the same period, the number of employed people went up from 8.4 million to 15.6 million. As a result, labor productivity fell from 1.29 million Rial per employee (17,488 US$) in 1974 to 1.19 million Rial (680 US$) in 2000; see Table 2-3.

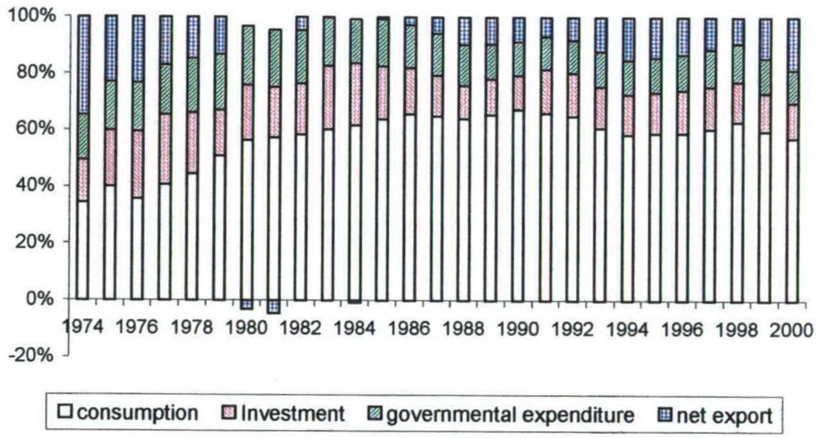

Figure 2-3. Shares of GDP components in constant 1982 market prices

Although labor productivity decreased during the period before 1989, and as a result during the total period 1974-2000, the country succeeded in improving its labor productivity during the third period, with a growth rate of 2.3% per year; see Table 2-3. The annual growth rates for the whole period and the period after the ceasefire show that some improvement has been achieved for the latter period.

Bottom line is that the average growth rate of population in 1974-2000 was about 2.7%, while the economy has not responded to this growth. The real GDP growth has been 2.1% per annum on the average in the same period, resulting in an annual decrease of per capita GDP by 0.6%.

Consumption and capital formation

As shown in figure 2-3, the share of private expenditure in real GDP has grown from 34% in 1974 to more than 67% in 1990 and then decreased again slightly to 57% in 2000. Adding government expenditure of about 11%, the national expenditure is 69% of GDP.

The share of capital formation in 1974 was 14.9%, increased to 24.8% of GDP in 1977, the highest value in the whole period, and showing, with some swings, a downward trend. The share was 12.6% in 2000. Compared to other developing countries the share of capital formation in Iran is relatively low.

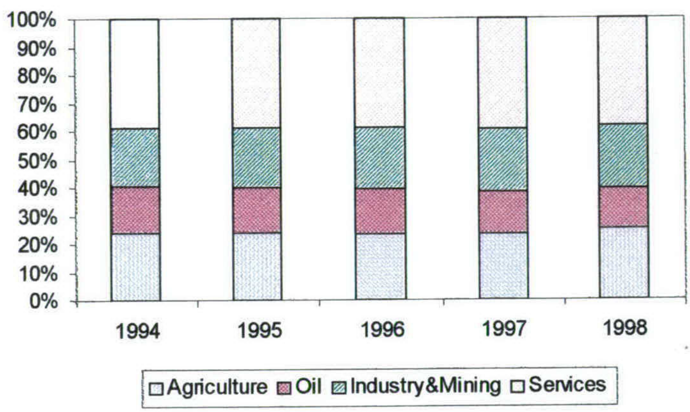

Figure 2-4. Contribution of economic sectors in generating GDP

Compared to more successful developing economies, an investment share of 14.1% is a low. For example, the shares of capital formation in real GDP of China, Malaysia, South Korea, and Indonesia are 43%, 39%, 38%, and 29%, respectively (IMF, 2000). The share of capital formation in GDP of OECD countries is also considerably larger, denoting a bottleneck in Iran's GDP growth. Capital formation in some selected OECD countries is, United Kingdom (19.6%), USA (16.7%), the Netherlands (20.0%), Australia (23.8%), and Germany (21.1%). These shares are rather steady already for some time and show no drastic swings (IMF, 2000).

Figure 2-4 shows the contribution of each major economic sector in total GDP during recent years. Notice that the service sector in Iran is large.

Government policy

One of the most difficult points to discuss here is the development of government policy in Iran. After the revolution of 1979 and during the Iraq-Iran war (1980-1988) the economy of Iran has actually become a centrally planned one. This had lead to a very complex situation in which almost all aspects of the economy were/are run by the state, and this is certainly the case for the energy sector. With the revolution, most privately owned banks and energy companies were nationalized, as were many other activities. Almost ten years after the revolution, by the end of the Iraq-Iran war, the Iranian economy was, by international standards, in a very bad condition. Imports, exports, and most other activities depended on a complex system of government approval, and the prices of most basic goods were heavily subsidized. The state control of the economy did, however, have several positive effects also. Social indicators, such as poverty reduction and the closing of the gender gap, have improved considerably and Iran serves as an example to comparable countries (World Bank, 2001a).

Immediately after the end of the war, Iran developed its first five-year development plan (FYDP) to improve its economy, and has been working on this ever since. In March 2000 the parliament accepted the third FYDP. We will not discuss all problems, but only list those relevant for our research:

- In the past the Iranian government has used up to twelve different exchange rates for various categories of goods. The exchange rate for an imported good was (and in many cases still is) set by the government, based on its view on the strategic importance of the good. In recent years only three exchange rates (see below) were used, and in 2002 Iran switched -in principle- to one market based exchange rate.
- There are many tariff and non-tariff barriers for imported goods. The government has made a list of items that can be imported relatively easy.
- Exports are bound by foreign exchange rules, minimum prices for exported goods, quality regulations, and licensing.
- Many domestic goods are either explicitly or implicitly subsidized. The amount of (implicit) subsidies, although difficult to estimate exactly, amount to more than 15 and possibly even more than 20% of total GDP.

- State control over the prices of many goods has lead to continuously decreasing real prices.
- Las but not least, to finance many of the policies, the increase in liquidity in Iran has been as high as 30% per year, leading to double-digit inflation rates as well.

All this has resulted in an economy that depends more than any other on government policy decisions and on state control. It is certainly not a textbook economy and cannot be treated as such. Given the goal of this research, which is to provide insight into the possibilities of domestic energy policy and domestic energy saving, we will not aim at providing complete description of the total economy. For this research we will not try to model the total economic structure, but we will only build a descriptive model of Iran's domestic energy sector, augmented with a limited number of macroeconomic relations; see Chapter 6.

2.3 The role of energy in Iran's economy

In this section the role of energy in Iran's economy is discussed in general terms. The basket of primary energy reserves, the transformation of energy for domestic use and the losses of the transformation-sector, energy intensity, as well as energy consumption in various sectors are analyzed.

Primary energy reserves in Iran

Based on the latest available information, the oil in place reserve in Iran is about 425 billion barrels, of which 89.4 billion barrels is recoverable in primary and secondary production; that is, with 90% certainty this amount of oil can be recovered using current technology (this is also called proven reserves). The average oil recovery factor is about 21% of the total reserve. With the current level of technology, production-reserve ratio is about 65 years (Ministry of Energy, 1999). This amount of oil reserve is equal to 8% of the world reserves and 10% of OPEC's reserves.

Iran's recoverable natural gas reserves are about 24.5 trillion cubic meter (TCM) or 882 trillion cubic feet (TCF). This is equivalent to about 148 billion barrel of crude oil. With the current level of production and technology, Iran's production-reserve ratio is about 160 years. Iran owns about 16 percent of the world gas reserves.

Apart from oil and gas, Iran also has a large potential of other energy resources:

- Total reserve of coal is estimated at 12.7 billion tones.
- Iran's hydroelectric potential is more than 42,000 megawatt, of which only 4.7% is currently used.
- Iran's solar energy potential is estimated to equal 130 billion barrel of oil equivalent.
- The potential for wind energy is about 6,500 megawatts.

Energy production and consumption

From 1974 to 1998 the consumption of primary energy has increased more than 458%, from 142.4 to 795.1 million BOE, final energy demand increased by the same percentage, and the demand by the primary energy sector by including the losses 462%. The main primary energies supplied to the domestic market are crude oil and natural gas, but also some hydroelectricity, solid fuels, non-commercial energies, and renewable energies such as wind and solar are used. Next we discuss all energy carriers used in more detail.

Crude oil

Iran's crude oil production capacity was about 6 million barrel per day before the Islamic Revolution of 1979. After the revolution, crude oil production decreased reaching its lowest level of 1.28 million barrel per day in 1981. The production capacity in 1998 was 3.84 million bbl/d, and the daily average production was 3.73 million barrel. Figure 2-4 depicts the trend of oil production from 1974 till 1998 and shows that a sharp drop in production occurred after the revolution, which was amplified by the Iraq-Iran war.

Iranian experts believe that maintaining a production capacity of almost 4 million barrels per day in the years to come will be difficult. To keep this production level, Iran has to invest much, particularly in gas injection projects to raise the pressure of dying reservoirs. Achieving a higher level of production capacity is only possible when a considerable amount of hard currency is invested in those fields that are currently producing, and in the development of new fields. However, such a policy would be at odds with Iran's OPEC quota, which does not even permit the use of all capacity currently available. Although the excess capacity cannot be used currently because of quota limitations, it can play a critical role in a time of OPEC supply shortage. The latter provides an opportunity to recover the costs of excess capacity and make a profit. For example, the cut in Iraqi production because of political problems and the reduction in Venezuela's production offered members with excess capacity to profit from the higher prices

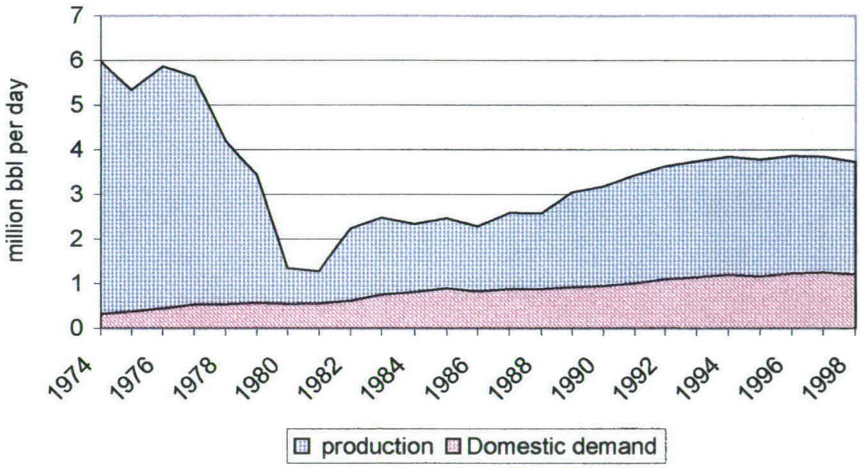

Figure 2-4. Oil production, domestic demand for oil, and oil export

Figure 2-4 shows that the amount of crude oil supplied to meet domestic demand has grown from 0.32 million barrel per day in 1974 to 1.21 million in 1998. The average annual growth rate of the domestic demand for oil from 1974 to 1998 was 5.56%. However, its share in the domestic energy basket has come down from 81.95% in 1974 to 55.72% in 1998 due to the gas for oil substitution policy, especially since the early nineties; see Figure 2-5.

As shown in Figure 2-4 the domestic consumption of crude is currently about 33% of production, and this share is increasing, threatening the export of crude oil and thus Iran's main opportunity to earn hard currency. So without a change in Iran's domestic energy policy, a further decrease of oil available for export should be expected.

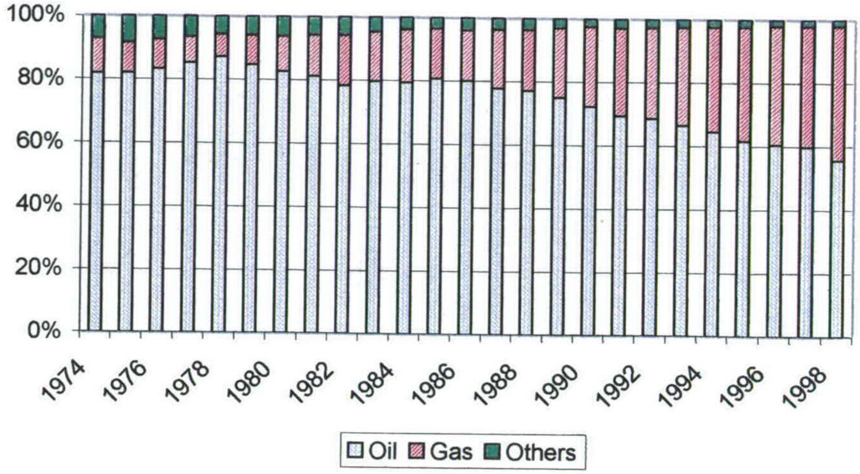

Figure 2-5. Share of the main energy carriers in Iran's primary energy basket

Natural gas

Since Iran has abundant natural gas reserves (24.3 TCF which is 15.8% of world reserves and 1.65 time more than its proven oil reserves), a major change in the domestic energy market over the last decade has been the replacement of oil products by natural gas. This policy will be continued in the future, because it has many advantages. First, it increases the amount of oil available for export. If we assume that the share of crude oil in Iran's domestic energy supply would have stayed at 82.7%, this would require about 50% of the OPEC quota for Iran. Second, the use of natural gas is more energy efficient in refineries when transforming crude oil into petroleum products, and power plants based on natural gas are on average more efficient also. Third, natural gas is less emitting in terms of greenhouse gasses than oil products. Finally, one should keep in mind that natural gas is more difficult to export. Investing in international gas infrastructure faces many political problems, because the gas pipelines have to cross several borders. This is especially true for Iran, which is a difficult part of the world from a political point of view. LNG on the other hand requires larger investments than the international oil trade does.

Iran has tried (and will try) to export its natural gas. Iranian gas is currently exported to Turkey, which is an interesting market. However, Turkey has contracts with other neighboring and gas producing countries also. From a Turkish point of view this increases the certainty of supply. This also shows that there is tight competition in this region by Iran's neighboring countries.

Iran had a contract with the USSR also, but this contract has been canceled after the collapse of the USSR. As a result, the best way for Iran to utilize its natural gas reserves is by domestic consumption while trying to extend its share in regional foreign markets. Finally, many countries in the region try to export their natural gas, which means there is more competition on the market for gas than on the market for oil. Russia, Azerbaijan, Turkmenistan, Qatar are among the countries in the region that would like to export their gas to the same markets as Iran, i.e. Turkey and then to Europe, Pakistan, and India.

The primary consumption of natural gas in 1998 (336.9 MBOE) is 21.6 times that of 1974 (15.6), this is an average annual growth of 12.8%. For the period 1988-1998 this growth rate is even bigger, 15.5%. As a policy it was decided in 1998 to expand the domestic usage of natural gas. As a result the share of natural gas in total primary energy demand has grown from 19.3% in 1988 to 42.4% in 1998.

Despite the high share of natural gas in Iran's primary energy basket, the share of oil in total energy consumption is still high. This is one of weak points in Iran's energy supply, improvement of which this research is trying to analyze.

Other energy resources

Currently the shares of hydroelectricity, solid fuels (mainly coal), and other fuels (non-commercial fuels as wood and charcoal), in Iran's total primary energy consumption are 1.3%, and 1.9% respectively. The share of renewables is negligible. In general Iran's hydroelectric power is directly connected to the overall electricity grid; only in some isolated areas it is consumed locally. Major consumers of coal are iron and steel manufacturers. Wood, charcoal, animal and plants wastes are used only in remote rural areas, mainly as household fuels.

Losses and fuel use in the primary energy sector

Primary energy supplied into the domestic energy sector has to be transformed into energy that can be used by end users. Refineries produce petroleum products and power stations produce electricity. These final energies have to be transmitted or transported to the final consumers. Transformation and transport themselves use energy also. However, the energy efficiencies of these processes in Iran are low, certainly compared to state of the art processes, but also to other countries. The difference between total primary energy demand (TPED) and total final energy demand (TFED) gives the amount of own energy consumption and energy losses of the energy sector; see Figure 2-6. This amount has increased from 30.7 million BOE in 1974 to 172.6 million BOE in 1998, indicating an annual 7.2% growth rate. The ratio of total own consumption in the energy sector in 1998 as a percentage of total primary energy consumption is 21.7%, indicating substantial potential for conservation.

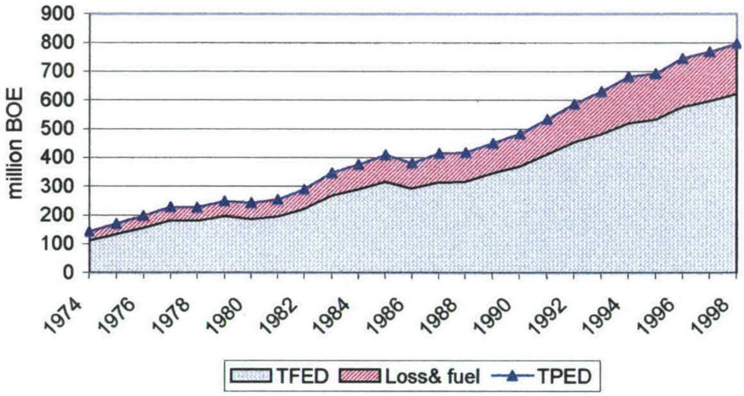

Figure 2-6. Total final and primary energy demand; loss and fuel of energy sector

The power sector is responsible for the major part of its own energy consumption in the primary energy sector. With the development of the domestic electricity market in combination with the low electricity prices the sector's energy losses have increased. As a percentage of the total own energy consumption by the power sector has grown from 38.8% in 1974 to 55.0% in 1998.

Final energy consumption

Total final energy demand in 1974 was about 111.7 MBOE or 0.31 MBOE/day; see Figure 2-7. With an annual growth rate of 7.2% it has reached to 622.5 MBOE or 1.7 MBOE/day in 1998. Petroleum products, with a share of 81%, covered the main part of this demand in 1974. The share of natural gas in final consumption was only 17% in that year. The share of petroleum products has decreased to 55%, whereas the share of natural gas has increased from to 35% in 1998, indicating once more the considerable changes in Iran's final energy basket.

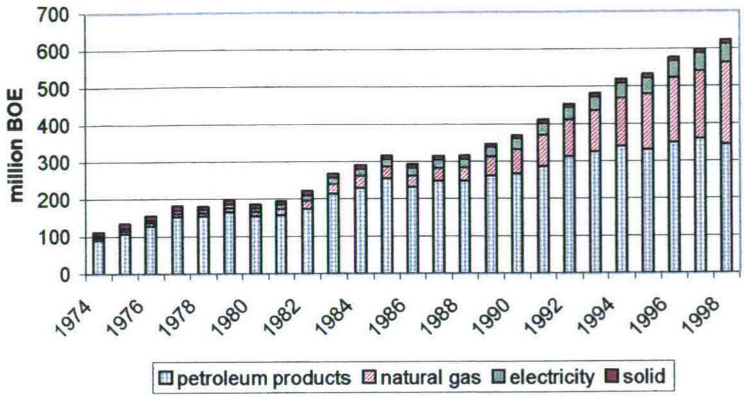

Figure 2-7. Final energy demand and its main components

The average annual growth rate of petroleum products was about 5.58% over the time period 1974-1998. At the same time, natural gas has grown at a rate of 13.26% per annum. Electricity demand has increased by 8.91% per year, coming from 9,152 million kWh (5.8 million BOE) in 1974 to 77,646 million kWh (48.9 million BOE) in 1998. The smallest share (2%) is that of solid fuels. Figure 2-7 shows that the petroleum products and natural gas meet the major part of Iran's final energy demand (about 90.1%). So hydrocarbon energies cover more than 90% of Iran's total final energy demand.

Energy demand in various economic sectors

Figure 2-8 shows final energy demand by the main economic sectors in 1998. With a share of 36% the Residential & Commercial sector is the largest consumer of energy. Transport and Industry are two other major consumers, responsible for 25% and 24% respectively. The agricultural sector is the smallest consumer of energy. In the following the details of each sector are discussed.

Remark: Unfortunately, the energy usage data per economic sector are not available for the total period and these data are not reliable; also see Section 5.4.

Next, we discuss the energy consumption in each sector in more detail.

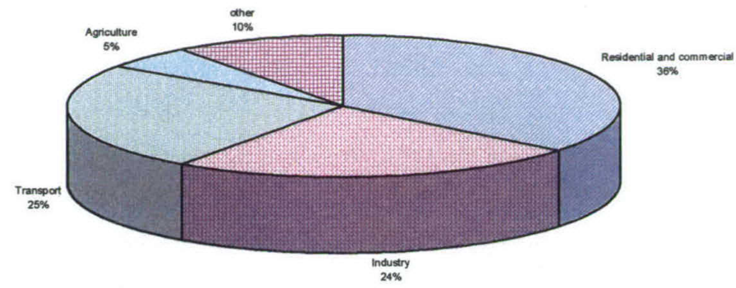

Figure 2-8. Shares of final energy consumption by economic sector in 1998

Residential & Commercial sector

Annual final energy consumption by the Residential & Commercial sector has grown on average by 7.8%, from 34.1 MBOE in 1974 to 222.3 MBOE in 1998. The share of petroleum products was 85.1% in 1974 and that of natural gas 0.25%. In 1974 the share of electricity and solid fuels were 8.5% and 6.1% respectively. As Figure 2-9 shows the fuel basket for this sector has changed drastically. Natural gas has replaced petroleum products especially since 1990. The annual growth rate of natural gas demand during the period is 28.9% while for petroleum products this is 5.4%. The main portion of the gas is used for heating and cooking.

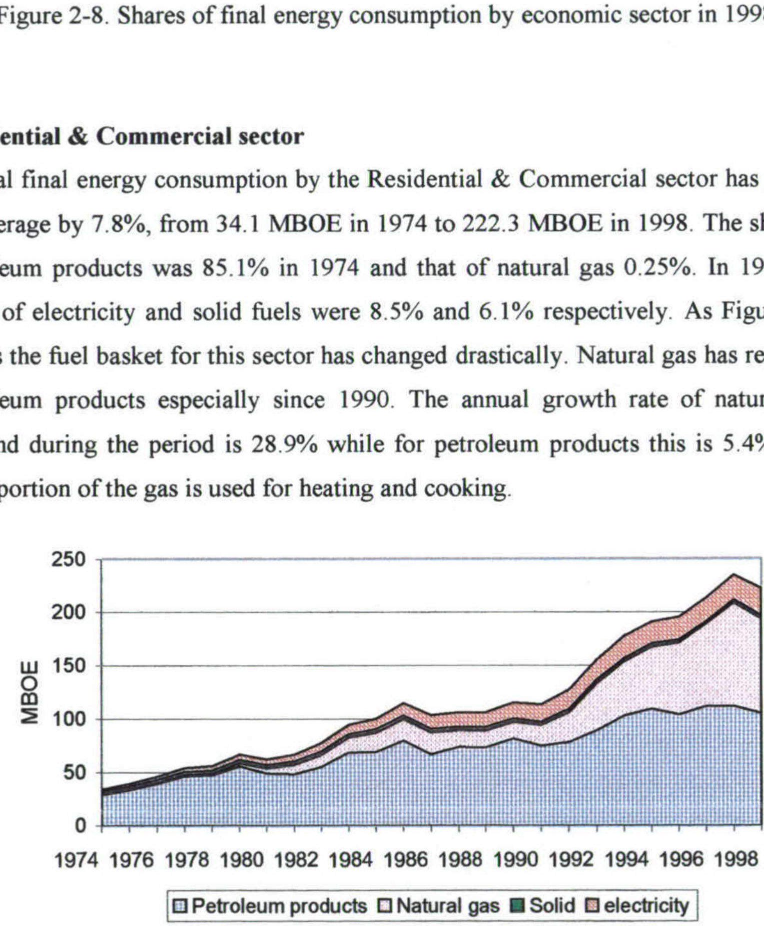

Figure 2-9. Fuel mix in Residential & Commercial sector

Transport sector

This sector is the second largest consumer of final energy. The consumption of the transport sector has grown from 26 MBOE in 1974 to 155 MBOE in 1998, an average annual growth rate of 7.3%. As one would expect, almost all consumption of this sector is in the form of petroleum products, although in recent years some vehicles use compressed natural gas (CNG), and LPG. In some urban areas, such as Tehran, some electricity is used for electrified trains, but the data on this usage are not available.

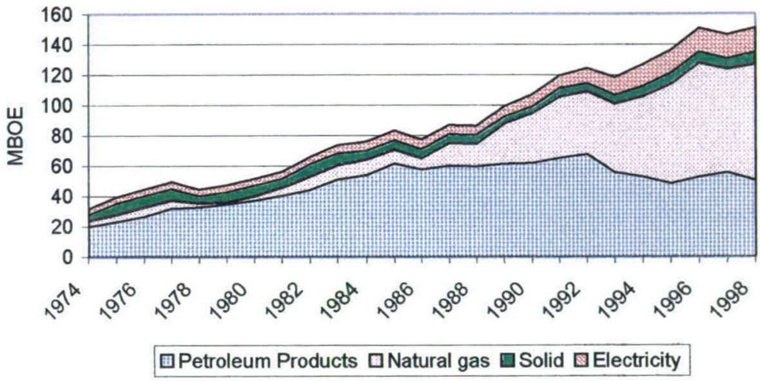

Figure 2-10. Fuel mix in Industrial sector

Industrial sector

The industrial sector is the third largest of energy user in Iran, with a share of 24% in 1998; see Figure 2-8. The average growth rate of final energy use in this sector was 6.5% within 1974-1998. Total energy consumption was 31.8 MBOE in 1974 and reached a level of 150.9 MBOE in 1998.

As shown by Figure 2-10, in contrast to the Residential & Commercial sector, the main energy carrier of this sector is natural gas, with a share of 50.7% in 1998. The shares of petroleum products, electricity, and solid fuels are 33.3%, 10.7%, and 5.3%, respectively. Compared to the other sectors the share of electricity in energy consumption of the Industrial sector is large.

Agriculture sector

Final energy consumption in the agriculture sector was 6 MBOE in 1974, which with an annual growth rate of 7%, reached to 32 MBOE in 1998. The share of this sector has always been less than 6% of total final energy consumption. Petroleum products has always been less than 6% of total final energy consumption. Petroleum products cover about 87.7% of total final energy used in this sector, while the remaining demand (12.3%) is met by electricity.

Other final energy use

In Figure 2-8 about 10% of total final energy is consumed in miscellaneous activities titled as "other", which include petrochemical consumption, and some other energy and non-energy use.

In conclusion, the largest consumer of final energy is the Residential & Commercial sector, with a considerable capacity to replace petroleum products by natural gas. With a good pricing policy CNG can be economical in the transport sector, which offers a tremendous opportunity to conserve petroleum products. Although the share of natural gas in industry is high, there still is room for natural gas replacement at affordable prices.

Energy intensity

The amount of primary (or final) energy used per unit GDP is an important and often used indicator for the energy intensity of an economy. Although this indicator should be used with care, it can be used to compare economies (Sun, 1998) and for energy professionals has a distinctive informational value. We calculated the energy intensity based on total primary as well as total final energy; see Figure 2-11.

As the figure shows, Iran's primary energy intensity has grown from 13.1 BOE per one million Rial of GDP (at constant 1982 prices) in 1974, to 39.2 in 1990, and reached 46.6 BOE in 1998. The annual average growth rate of primary energy intensity over the total period was 5.3%. Despite some fluctuations in recent years, the trend in energy intensity has been upwards. The energy intensity of based on final energy was 10.3 BOE per million Rial of GDP in 1974 and 36.5 in 1998, so the growth rate was the same as that of primary energy demand.

In the transport sector the energy intensity was 45.1 BOE per million Rial real gross value added (GVA) in 1974 and grew to 146.3 BOE per million GVA in 1988, but improved after the ending of the war to reach 118.6 BOE in 1998; see Figure 2-12. This sector is by far the most energy intensive one. The average annual growth rate of energy intensity was 4% over 1974-1998.

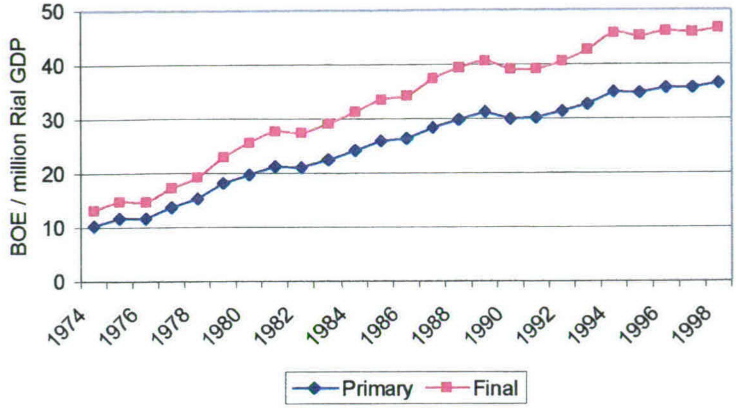

Figure 2-11. Energy intensity based on primary and on final energy demand

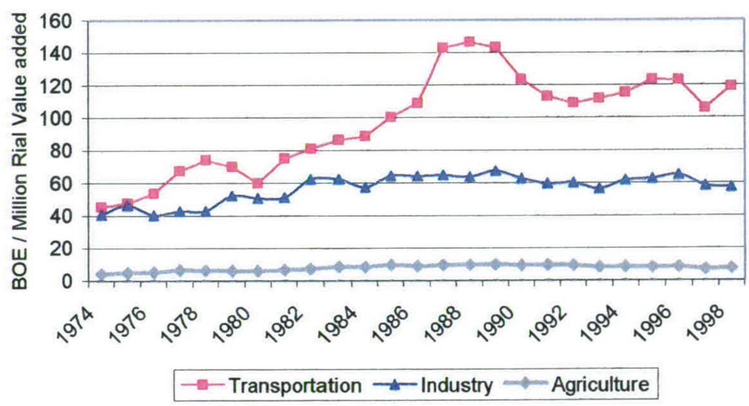

Figure 2-12. Final energy intensity

The energy intensity of the industrial sector shows a different trend. The overall annual average growth rate was 1.4% over the evaluation period 1974-1998. In recent years the intensity even shows a downward trend, mainly because of Iran's improved economic situation due to high oil prices. Figure 2-12 clearly shows that the Iraq-Iran war resulted in an upward trend. During the war Iran's industry worked around 50% of its nominal capacity due to lack of funding, especially hard currencies (which were historically injected by the government into the industrial sector at favorite exchange rates), and the lack of (raw) materials. After the war idle capacities favorite exchange rates), and the lack of (raw) materials. After the war idle capacities were used again and capacities were used more efficiently, causing the industrial energy intensity to come down slightly.

Energy intensity in the agriculture sector is low, 4.3 BOE per one million Rial real GVA in 1974 and 7.5 BOE in 1998, an annual growth rate of 2.3%.

Since the growth rates of the three sectors discussed here are below the overall growth rate, this can only mean that the Residential & Commercial sector shows a much higher growth rate in energy demand.

2.4 Energy Prices and Implicit Energy Subsidies

In every country energy pricing is one of the most important energy and environmental policy instruments. In most countries energy products are a revenue raiser for the government. In most developed countries the border price of an energy carrier is less than half of the consumer price. However, for Iran this does not hold. Although the Iranian government sets the price of energy carriers, these prices have not been set in an economically efficient way. For one, the real domestic prices of all energy carriers have gone down almost every year over the last decade; also see Figure 2-14. Furthermore, no attention has been paid to the relative prices. As a result, the prices of, for example, gasoline and electricity are closer to their economic prices than the prices of kerosene or gas oil.

Although aware of these problems, this has not lead to drastic changes in Iran's energy pricing policy. Only in the second five-year plan (1995-1999) were nominal energy prices adjusted, but as we shall show, in real terms these adjustments were insufficient. However, further significant price adjustments planned for the third five-year plan (2000-2004) have been abandoned. Recently the Iranian parliament has decided to increase all nominal energy prices for end-users by 10% and future price increases will not exceed this. With an expected inflation rate of over 20%, the real prices of energy carriers will go down once again. Given the fact that oil is the main source of foreign revenue, in combination with the fact that Iran is hardly able to produce enough oil to meet its OPEC quota, the potential for export will be reduced once more.

This policy of decreasing real energy prices has resulted in large implicit subsidies. The size of these subsidies are and have been the subject of much discussions, both within Iran (Mazraati and Fathollahzadeh, 2000; Saboohi, 2001) and between Iran and aiding institutions as the IMF and the World Bank (World Bank, 1999 and 2001b). Here we will estimate the size of the implicit subsidies on final energy demand using the border prices of petroleum products, natural gas, and electricity.

One could, and many people in Iran do, argue that border prices are not the appropriate prices to estimate implicit subsidies. Iran is rich in oil and therefore the production cost should be used. However, Iran's current oil production capacity is only just above (and some say on average even below) its OPEC quota. All oil produced, or petroleum products obtained from it, available for export can be sold. Furthermore, Iran's refinery capacity is insufficient to meet all domestic demand for gasoline. Given this situation there is no excess supply, so the border prices for petroleum products are the appropriate prices to calculate the implicit subsidies.

The main argument for low energy prices is that the Iranian people should benefit from Iran's main resource. Since Iran is thought to have abundant energy resources, energy should be available for the Iranian people at low prices, and some used to argue even for free. However, this implicit income policy has lead to great distortions in relative prices, which in turn has resulted in misallocation of the energy resources. The question is not if the Iranian people should benefit from Iran's resources, the question how can they benefit the most. Income policy through low energy prices (and many other products) deprives the people from making their own choices. If they would have the money equivalent of all implicit subsidies to spend at their own discretion, they might make other choices than they are obliged to make now.

In the following production cost of petroleum products and the nominal and real prices of energy carriers are discussed, as well as border prices. The latter are then used to estimate the implicit subsidies on energy.

2.4.1 Petroleum Product Production Cost

The Ministry of Energy of Iran (1998, p 86) calculated that the average cost of one liter of a composite barrel of oil products is less the one US$-cent for all Iranian refineries. Most likely these calculations are not based on the economic costs. If they are true, the profit margin of Iran's refineries would be the largest the world. This is in sharp contrast with the fact that some of them face continuous losses also.

Table 2-4. The characteristics of Iran's refineries in 1998

Refinery Name	Remaining lifetime*	Replacement cost	Current value of capacity	Depreciation cost (annual)	Active refining capacity
Unit	Year	US$/bbl	US$/bbl	Million US$	1000 bbl/d
Tehran II	2	13000	1040	66.1	115.01
Isfahan	6	12500	3000	205.1	329.48
Tehran I	0	10000	0	0	115.01
Shiraz	0	10000	0	0	49.79
Tabriz	4	10000	1600	48.2	102.6
Arak	20	10000	8000	112.2	161.6
Bandar	24	10000	9600	170.8	227.67
Kermanshah	0	8000	0	0	22.41
Abadan	6	2250	540	44.1	393.69
Lavan	4	2030	320	2.6	27.87

* Lifetime of a refinery assumed to be 25 years. Source: Pakravan, 1999

Pakravan (1999) provides us with a more serious estimate of the cost price of domestically produced petroleum products, by analyzing all Iranian refineries and their refining patterns. The following cost items were considered:

- Transportation cost of crude oil from Persian Gulf to the refineries;
- Overhead costs;
- Refinery costs (including depreciation); and
- Distribution cost of petroleum products to the major distribution locations.

To calculate the depreciation cost, the refineries were valued at the replacement cost of a new similar refinery. The investment cost of installing one barrel of refining capacity ranges between US$ 2,030 and US$ 13,000 for simple and complicated refineries respectively. Table 2-4 contains a brief specification of Iran's refineries. As it can be seen all refineries are old and already beyond their economic lifetime, except for Arak and Bandar.

In all calculations a free market exchange rate of 8,000 Rial per US$ was used. The price of oil was set at the FOB Persian Gulf price of 10.59 US$/bbl. Table 2-5 contains the estimated cost price of refined products in Iran as well as Persian Gulf FOB prices. The table shows that the cost price of refined products in Iran, when based on economic cost, is close to the international prices.

Next we look at domestic and international energy prices.

Table 2-5. Iranian supply cost and international prices of petroleum products in 1998

Products	Cost Price US$-cent per liter	Persian Gulf FOB price US$-cent per liter
LPG	8.0	7.8
Gasoline	9.9	9.7
Nafta	8.7	8.6
Kerosene	9.5	9.3
Gas oil	8.5	8.3
Fuel oil	6.4	5.9

Source: Pakravan, 1999.

2.4.2 Energy Prices

Prices of goods and services determine the allocation of resources in every market economy. For this reason, changes in relative prices will cause changes in resources allocation. Energy prices affect consumer welfare and the cost of production, because energy costs are part of every household's budget and every manufacturer's cost structure. However, in Iran the government and not the market determine energy prices; energy prices are administered prices. Before the revolution of 1979, as well as during the Iraq-Iran war, the nominal prices of energy products were kept almost constant; see Figure 2-13. After 1988 energy prices were adjusted somewhat; the price of gasoline has changed more than the prices of other products, because it is regarded a luxury product rather than an essential good.

In the first five-year plan (1989-1993), special attention was paid to energy demand. In order to control the growth rate of energy demand, as well as to decrease implicit energy subsidies, prices of energy carriers in nominal terms were increased. At the end of the first five-year plan the price of gasoline was 50 Rial per liter (3 US$-cent), that of kerosene 15 Rial (0.9 US$-cent), of gas oil 10 Rial (0.61 US$-cent), and that of fuel oil 5 Rial (0.3 US$-cent) respectively[2]. The weighted average of all nominal prices of petroleum products was 16 Rial, which is equal to 0.97 US$-cent.

[2] Based on the official 1993 exchange rate of 1646.3 Rials per US$.

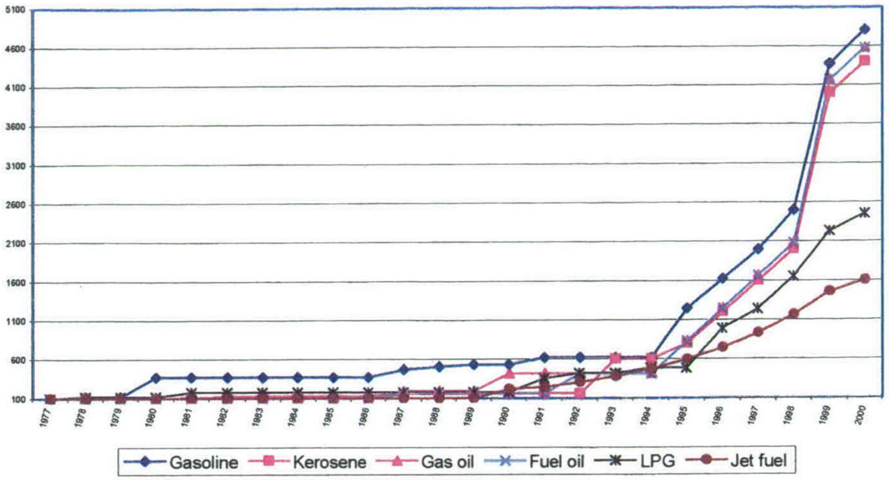

Figure 2-13. Nominal price index of petroleum products in Iran (1977=100)

Due to the devaluation of the Rial-US$ value, domestic energy prices in terms of US$ have not increased considerably. Table 2-6 contains the three most important exchange rates for Iran. The table shows that large differences in dollar value will occur depending on the exchange rate used. However, the dollar prices are low for all three of the exchange rates.

Table 2-6. Exchange rate of the Rial per US$

Year	*Free market*	*Non-oil export rate*	*Official oil export rate*
1992	1,498	NA	65.7
1993	1,810	NA	1,646.3
1994	2,808	NA	1,749.0
1995	4,064	2,897	1,747.5
1996	4,446	3,008	1,751.7
1997	4,782	3,008	1,752.5
1998	6,468	5,395	1,752.5
1999	8,682	7,645	1,752.5
2000	8,188	8,078	1,752.5
2001	7,994	7,920	1,752.5

Source: Central Bank of Iran, "Economic Indicators", various issues.

Table 2-7 shows that the price of gasoline in Rial has increased by 34% per year over 1994-2000, whereas it has increased by only 14.9% per year in US$-terms when using the free market exchange rate. The same holds for other energy carriers. The weighted average of the petroleum products was 44 Rial in 1996 and 75 in 1999, when using the free market exchange rate. The same holds for other energy carriers. The weighted average of the petroleum products was 44 Rial in 1996 and 75 in 1999, which is equal to only 2.5 and 4.3 US$-cent per liter respectively at the most favorable exchange rate, the official oil export exchange rate; see Table 2-6.

Table 2-7. Iran's nominal prices for petroleum products in Rial and US$-cents

Year	Gasoline	Kerosene	Gas oil	Fuel oil	LPG	Jet fuel
	Rial per Liter					
1994	50	15	10	5	27	24
1995	100	20	20	10	27	30
1996	130	30	30	15	55	37
1997	160	40	40	20	68	47
1998	200	50	50	25	91	58
1999	350	100	100	50	123	73
2000	385	110	110	55	135	80
1994-2000	34.0%	33.2%	40.0%	40.0%	26.8%	20.1%
	US$-Cent per liter using the free market exchange rate					
1994	1.8	0.5	0.4	0.2	1.0	0.9
1995	2.5	0.5	0.5	0.2	0.7	0.7
1996	2.9	0.7	0.7	0.3	1.2	0.8
1997	3.3	0.8	0.8	0.4	1.4	1.0
1998	3.1	0.8	0.8	0.4	1.4	0.9
1999	4.2	1.2	1.2	0.6	1.5	0.9
2000	4.7	1.3	1.3	0.7	1.6	1.0
1994-2000	16.2%	15.1%	22.1%	22.1%	9.0%	2.2%

Source: Energy Balance of Iran, 1998; Economic trends, Central bank of Iran, 1999

In comparison, the price of premium leaded gasoline in OECD Europe in 1999 was 89.7 US$-cent per liter. In the many European countries prices were even higher. In, for example, Norway and France the 1998 pump prices were 1.065 US$ and 0.901 US$ respectively (IEA, 2000). (These prices include about 70% taxes and levies.) One can also compare the prices in Table 2-7 with the average 1999 international prices. For gasoline, gas oil, and fuel oil the Rotterdam spot market prices were 13.6 US$-cent, 13.8 US$-cent, and 6.1 US$-cent respectively (OPEC, 1999). So even compared to these bulk market prices without taxes the Iranian consumer prices in US$, which cover supply costs and taxes also, are very low. Finally, another study, comparing fuel prices all over the world (Metschier, 1999), states that the untaxed benchmark retail pump price for gasoline is US$-cents 21 and that for gas oil 18 US$-cents. These large differences between prices all over the world and the Iranian prices

As energy prices play an important role in the production costs of goods and services, it is difficult for the government to change these real energy prices rapidly without causing social unrest. That is one of the reasons the Majlis, the Iranian parliament, refuses to approve energy price increases in line with inflation.

The prices of electricity and natural gas in 1998 were 62 Rial (3.5 US$-cent) per kWh and 39.4 Rial (2.2 US$-cent) per cubic meter respectively, which are extremely low in comparison with developed as well as developing countries also.

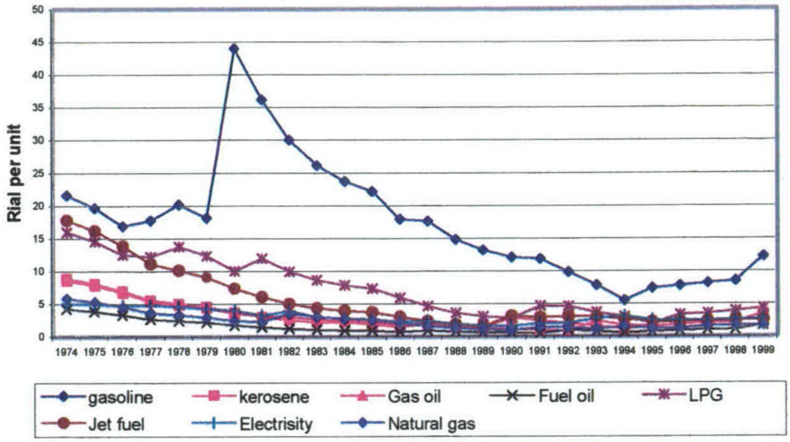

Figure 2-14. Real domestic energy prices

As Figure 2-14 shows, despite Iran's larger nominal price increases of petroleum products, electricity, and natural gas during the period 1994-2000, this has not lead to increases in real prices, because of Iran's high inflation rate (20.8% annually between 1994 and 2000). So in real terms, prices of energy have been going down for a long time. Only gasoline experienced a somewhat higher real growth rate in recent years. As a result of the very low real prices of energy products, energy users in Iran have no urge to use energy efficiently. This holds for all economic sectors.

Although some policy makers and representatives of congress, as well as independent researchers are convinced a substantial up-ward adjustment of Iran's domestic energy prices based on sound economic reasoning is required, no decisions to achieve this have been taken so far. Iran lacks a sound energy pricing mechanism based on the opportunity cost of each energy carrier, equal to the pricing of natural gas based in the Netherlands, where, for example, the price of natural gas for based on the opportunity cost of each energy carrier, equal to the pricing of natural gas based in the Netherlands, where, for example, the price of natural gas for households and small business is based on the trend in the international price of heating oil. Also a long run strategy for the process of energy price determination in Iran is still absent.

In the next paragraph we will estimate the implicit subsidies on energy, which can be interpreted as negative taxes also. In the light of long term planning, these negative taxes should gradually vanish (World Bank, 1999 and 2001b), and in the end, as a policy instrument and government revenue raiser, positive taxes could emerge.

2.4.3 Implicit Energy Subsidies in Iran

In economics, subsidy is defined as "...a payment made by the government (or possibly by private individual) which forms a wedge between the price consumer pays and the costs incurred by producers, such that price is less than marginal costs." (Pearce, 1986). In case of an implicit subsidy the government does not make an actual payment, but its policy results in a wedge between the economic value of a good or service and the price the consumers pay. In many countries endowed with an exhaustible resource this occurs when the government supplies the good extracted from the resource (or goods produced from the extracted good) to the domestic consumers at a price below the opportunity cost of the good. As was shown above, this is the case for energy products in Iran.

The Iranian consumers value a marginal barrel of (say) fuel oil at the current price the same as they value other goods they could buy for the same amount. Exporting the fuel oil would result in a larger amount of money and if given to the consumers they would be able to buy more other goods and thus increase their welfare. Since the prices of petroleum products are below their domestic production costs, even pricing them at that level would lead to an increase in welfare.

What should be used as the opportunity costs of energy products in Iran, marginal production costs or border prices, needs some thought. As was argued above, Iran has no excess supply capacity. Furthermore, due to the life cycle of oil reserve depletion, new investments are required to keep production at its existing level. This research was induced by the fact that the amount of oil available for export is falling due to strong increases in domestic demand. This means that Iran is not in a situation of excess supply. In such a situation the border prices of petroleum products should be used as the basis for the opportunity cost.

Note that this is similar to the pricing of natural gas adopted by the Dutch government when the huge gas reserve in the province of Groningen was discovered. Despite the fact that The Netherlands had an abundance of natural gas, certainly when it was only just discovered, the Dutch government based its domestic gas pricing policy on the international market prices of the main competitors (fuel oil for the industry and heating oil for domestic consumers) right from the start.

The model we use to calculate the subsidies per fuel is simple. Let PB_t^j be the border price of fuel j in US$, PD_t^j the domestic price in US$, and D_t^j the amount of fuel j used domestically. The implicit subsidy in US$ of fuel j, denoted by S_t^j, is defined as $S_t^j = (PB_t^j - PD_t^j)D_t^j$.

Of course an important problem to solve is estimating PB_t^j. For this we used several sources. In the following the estimation of implicit subsidies is calculated based on the following assumptions:

- The Singapore FOB prices for petroleum products are used as the opportunity cost. The freight rates from Singapore to the Persian Gulf are not included, since the products would be available from neighboring countries. Also the domestic distribution costs are neglected. This error is, however, small since these costs in Iran are rather low.
- For electricity the end-use pre-tax price of electricity in Turkey is used as an estimate for the opportunity cost of this energy carrier, which was 6.7 US$-cent per kWh in 1997. In Turkey private companies produce electricity and most of the fuels used in power generation have to be imported. Note that the Turkish price of electricity is close to the average price of electricity in OECD countries. In 1996 the Iranian Ministry of Energy stated that the average opportunity costs based on border fuel prices were 4.5 US$-cents per kWh[3]. Unlike FOB petroleum prices, it is difficult to get a good estimate of electricity border prices. We know that for 1997 it must be between 4.5 and 6.7 US$-cents. We do not want to overestimate the border price of electricity and given the fact that cost of the fuel

[3] Payam-e-energy, No. 13, Vol. 2, February 1997.

mix in electricity production in Iran will be lower than that of Turkey, 6.7 US$-cents per kWh is an upper bound. We (rather arbitrarily) set the border price for electricity in 1997 at the average value of the two prices.

- For the opportunity cost of natural gas we looked at two possibilities. Turkey imports natural gas from Iran at a price of about 0.08 US$ per cubic meter. On the other hand Iran pays on average only 4.2 US$-cents to Turkmenistan for usage of their gas in the North of Iran[4]. Since Turkmenistan is land locked and has no other opportunity to export gas, this price is most likely the minimum price. We set this border price of natural gas equal to the average price paid to Turkmenistan.

One last important factor that determines the size of the implicit subsidies is the exchange rate used to express domestic energy prices in US$ terms. For this we use the free market exchange rate.

The energy subsidies calculated below are based on total final energy demand (TFED in terms of the model of Chapter 6); the energy transformation sectors have not been taken into account.

Table 2-8. International border prices of energy carriers in Iran

Year	Jet fuel	LPG	Gasoline	Kerosene	Gas oil	Fuel oil	Nat. gas	Electr.
	\$/liter	\$/liter	\$/liter	\$/liter	\$/liter	\$/liter	\$/m^3	\$/kWh
1994	0.128	0.128	0.126	0.128	0.124	0.086	0.042	0.054
1995	0.141	0.141	0.139	0.141	0.137	0.095	0.042	0.055
1996	0.163	0.163	0.161	0.163	0.159	0.110	0.042	0.057
1997	0.157	0.157	0.155	0.157	0.153	0.106	0.042	0.056
1998	0.102	0.102	0.100	0.102	0.099	0.069	0.042	0.051
1999	0.139	0.139	0.137	0.139	0.136	0.094	0.042	0.054
2000	0.191	0.191	0.188	0.191	0.186	0.129	0.042	0.058

Source: Own calculations.

The results of our estimations are in Tables 2-8 and 2-9. Table 2-8 shows the border prices for the period 1994-2000 and Table 2-9 the total implicit subsidies. The latter amount to a staggering 14.4 billion US$ in the year 2000, based on a price of Iranian oil of 22 US$/bbl. The amount of implicit subsidies is, however, strongly affected by the price of oil. For example in 1998, when the implicit price of Iranian oil

[4] The reason why Iran imports gas in the North is that it would be more expensive to build a pipeline from its own gas resources to this region.

was only 10.8 US$/bbl, the amount of implicit subsidies was "only" 9.3 billion US$. On average the implicit subsidies are between ten and fifteen percent of the gross domestic product in dollar value.

The approach outlined here will also be used in chapters 6 and 7 to calculate future energy subsidies and the effect of opportunity cost pricing.

Table 2-9. Energy subsidies in billion US$

Year	Jet fuel	LPG	Gasoline	Kerosene	Gas oil	Fuel oil	Nat. gas	Electr.	Total
1994	0.10	0.40	1.31	1.43	2.74	0.97	1.64	3.55	12.15
1995	0.11	0.42	1.22	1.45	2.71	0.91	2.01	3.79	12.61
1996	0.15	0.54	1.46	1.91	3.54	1.07	2.72	4.44	15.83
1997	0.15	0.48	1.54	1.58	3.22	1.08	2.51	4.15	14.70
1998	0.09	0.31	0.91	0.95	2.04	0.64	1.88	2.60	9.29
1999	0.13	0.46	1.28	1.23	2.68	0.66	1.31	3.42	11.17
2000	0.19	0.68	2.03	1.78	3.79	0.88	1.39	3.64	14.38

Different assumptions lead to different estimates. The estimates per fuel by Pakvaran and reported in Subsection 2.4.1, are slightly lower than our estimates. This is most likely due to a different base year and differences in the oil price. In 1997 the Ministry of Energy estimated the amount of subsidies on petroleum products, electricity, and natural gas at 7.3, 2.5, and 1.35 billion dollars respectively (Ministry of Energy, 1997). Note that our estimates are at the high end of these previous estimates.

2.5 Energy Policy Formulation

In the previous sections the structure of Iran's energy sector was discussed. In the current section Iran's current energy policy intentions are outlined, although it should be kept in mind that these are intentions and still need to be translated into actual policies. As we shall show this is a cumbersome process in Iran (as is the case in many other countries).

After the ceasefire between Iran and Iraq in 1988, the first five-year plan for the period 1988-1993 was formulated and approved. Surprisingly, the energy sector was not approached as a separate issue in this plan. Electricity and the oil sector were discussed separately. The plan didn't contain any policy for restructuring the energy sector. The plan only discussed the functioning of the Ministry of Petroleum and the Ministry of Energy (which is actually only responsible for power), not a long-term plan.

In the second (1995-1999) and the third five-year plan (2000-2004), energy issues received the attention they deserve, and were discussed comprehensively. The new policies are in a separate section of the latest plan approved by Majlis. The adjustment of energy prices as well as liberalizing parts of the energy sector was approved in the second FYP.

In Subsection 2.5.1 the most important government bodies and the procedures followed are briefly discussed. In Sub-section 2.5.2 the main strategic policy intentions of the energy sector as formulated the third FYP are briefly discussed.

2.5.1 Decision Taking and Decision Making

The governmental decision making process is a complex one, and this certainly holds for Iran. There are two main lines, with many connections. There is an elected president and an elected parliament, the Majlis. The president is head of the executive branch of power. He and his cabinet develop the energy policy, which has to be approved by the Majlis first.

After approval by the Majlis, a proposal is sent to the Council of Guardians, which consists of six theologians appointed by the Supreme Leader and six jurists nominated by the judiciary and approved by the Majlis. This council must check all bills that pass parliament, to make sure they do not contradict Islamic law. The Council of Guardian is the most influential body in Iran.

If the Majlis and the Council of Guardians disagree, the Expedience Council will mediate. This council is active in policy-making and its members are prominent religious, social, and political figures. It advises the Supreme Leader, who also appoints the members.

The Supreme Leader is at the top of Iran's political power structure. The Supreme Leader - currently Ayatollah Ali Khamenei - appoints, among others, the clergy members on the powerful Council of Guardians, and he has to confirm the election of the president.

All these institutes have to agree when a new energy policy is introduced. It will be obvious that this is not simple, especially since the political views of the members of the different bodies differ considerably and an understanding of the relationships between all issues involved is often lacking.

Energy Policy formulation

At the highest level, the cabinet formulates energy policy. Four ministries and the Organization of Atomic Energy each have a task:

- The Ministry of Petroleum is responsible for oil and gas and all downstream activities;
- The Ministry of Energy is responsible for electricity;
- The Ministry of Mining and Manufacturing is responsible for coal;
- The Ministry of Agriculture is responsible for rural renewable energy; and
- The Organization of Atomic Energy is responsible for renewable and atomic energy. (This organization is the direct responsibility of President Khatami.)

Because energy plays such an important role in the Iranian economy, the planning of long term energy matters, such as the formulation of the five-year plan, and the yearly budget allocation prepared by the individual ministries, are coordinated by Management and Planning, an office under the direct responsibility of the president. Only then the coordinated plans are send to the parliament.

All financial consequences have to be approved by, what is called the Economic Council, which consists of high-level representatives of the president, the Central Bank of Iran, the Ministry of Finance and Economics, and the Ministry of Petroleum.

Because the Ministry of Petroleum is the most important ministry in the matter of upstream and downstream oil and gas, an organization chart of this ministry is added; see Figure 2-15. This figure will help to better understand the discussions in the remaining chapters.

The boxes at the top directly support the minister and are headed by a director general. The term deputy indicates a department within the ministry that is headed by a deputy-minister. The four companies are independent entities with a board of directors headed by a managing director that is appointed by the minister.

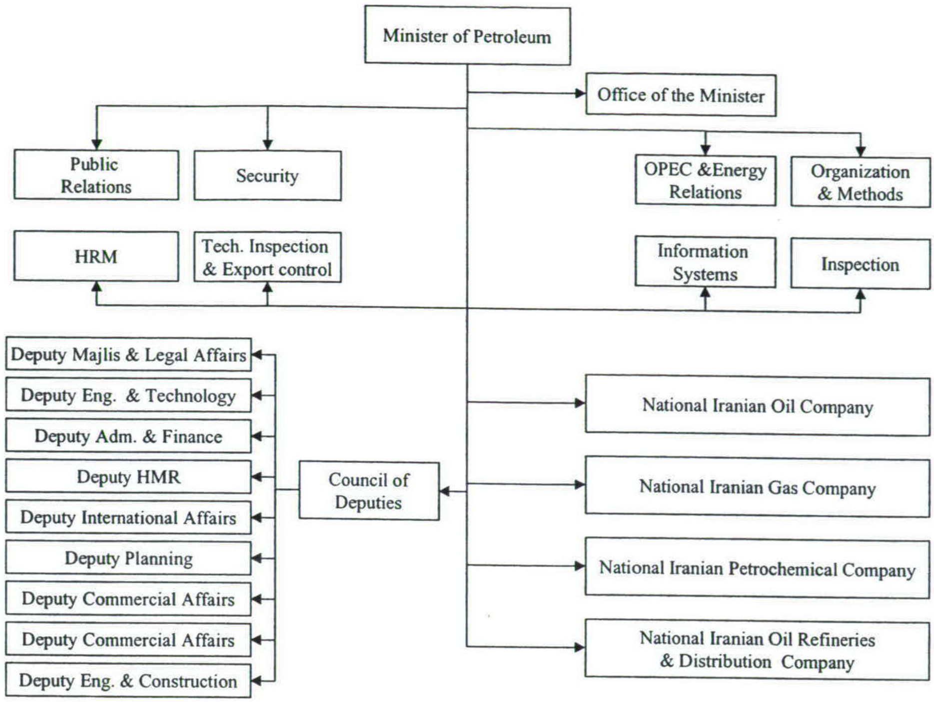

Figure 2-15. The Ministry of Petroleum and its subsidiaries

OPEC

OPEC is an organization that affects Iran's opportunities in the international oil market is OPEC, of which Iran is one of the founding members. OPEC's main goal is to stabilize the price of oil. To achieve this the ministers of petroleum of the member countries meet at least twice a year to discuss the production quota of each member state. Through this restriction of production OPEC tries to influence the international price of oil. The success of this policy has varied in the past. Table 2-10 shows some of the production quota for several periods. Since OPEC covers only part of all producers, OPEC also tries to convince other oil producing countries, such as Russia and Norway, to act in line with the OPEC decisions to stabilize prices. However, this policy is only occasionally successful.

Currently OPEC tries to stabilize the price of oil between US$ 22 and US$ 28 per barrel. A recurring problem is the fact that members with access production capacity cheat and produce more oil than is agreed upon. With the reduction in reserves outside OPEC and the expected increase in demand from developing countries, it is expected that the future role of OPEC in oil price stabilization will increase.

Table 2-10. OPEC's oil production quota in 1000 barrels per day

Country	Apr82-Mar83	Mar93-Jun93	2^{nd} half 1998	April 2000	September 2000
Algeria	650	732	788	811	836.6
Indonesia	1,300	1,317	1,280	1,317	1,358.6
I.R. Iran	1,200	3,340	3,318	3,727	3,843.8
Iraq	1,200	400	-	-	-
Kuwait	800	1,600	1,980	2,037	2,101
Libya	750	1,350	1,323	1,361	1,404.2
Nigeria	1,300	1,780	2,033	2,091	2,156.6
Qatar	300	364	640	658	678.8
Saudi Arabia	7,150	8,000	8,023	825.3	8,512.2
U.A.E.	1,000	2,161	2,157	2,219	2,289.4
Venezuela	1,500	2,257	2,845	2,926	3,018.8
Total OPEC	17,150	23,301	24,387	25,400	26,200

Source: ASB, 1999, EIA 2000.

Speed of the decision process

It will be clear that the complex and centralized structure of decision preparation and decision taking in Iran does not favor quick responses to changes in domestic or international energy markets. It also hampers negotiations with foreign oil companies and others, whose expertise is needed to improve Iran's energy sector capabilities. This problem is further complicated by the fact that the Iranian law currently prohibits direct investment in upstream energy activities by foreign companies. This means that production sharing contracts and concessions in which a foreign company owns (part of) the oil are not allowed. Only in downstream activities foreign investments are allowed nowadays.

2.5.2 Policy Improvement Plans

In the third five-year plan a number of domestic and international energy issues were addressed and policy intentions were formulated. Here we briefly state those issues that affect our analysis of the domestic energy market.

- Because Iran's oil production capacity is decreasing, priority will be given to investments to increase oil production and/or to improve the quality of production and supply. This should increase Iran's oil and gas production capacity (or at least keep it at its current level).
- Given the technical infrastructure currently available in Iran, the security, quality level, and reliability of the supply of electricity, natural gas, and petroleum products has high priority.
- The substitution of crude oil by downstream products that have a higher added value, such as petroleum and petrochemical products, and possibly electricity.
- Optimization of domestic energy consumption and conservation. To achieve this energy prices must be increased to the regional level. This should result in conservation and protection of Iran's natural resources.
- The government companies need to achieve financial self-reliance and create incentives for participation and involvement of the non-government sector of the economy in the energy market. Gradually this should result in the elimination of monopolies in electricity generation, oil and gas refineries, and the distribution of petroleum products and associated services. These companies should be managed and operated in a commercially viable way.
- Energy conservation programs shall be designed with incentives, such as financial support, for all economic sectors.
- When the companies are economically viable, the government will sell (part of) its shares in the holdings of state-owned companies to cooperatives and/or the private sector.
- The government will create an open and fair system to assign contracts for work related to the manufacturing of equipment and projects in the energy sector to private, cooperative, and governmental companies.
- The government will promote research in the energy sector with the aim to reduce the cost of finished products and the foreign currency component. Financial support for these research activities will be provided to the non-government sector, universities, and research institutes. The research aims at demand side management and the development of energy conservation plans.
- The different energy resources of the country (oil, gas, hydro, nuclear energy, coal, and renewables) shall be utilized according to their relative local advantages,

based on economic factors and environmental considerations. To this end the share of natural gas, electrical power, and renewable energies should increase.

The five-year plan's articles related to energy, were passed by the Majlis in March 2000, and are in chapter 15, titled Energy.

Although these intentions are far reaching and seem to cover all aspects of improving domestic energy consumption, it has to be said that the translation into actual policy is still far away and in some cases meets fierce political resistance. Most important, higher increases in energy prices, which were close to the inflation level during the second five-year plan, were actually abolished again for the third five-year plan period. Until now the increases were about 10% each year and this is expected to continue at least till 2004, but most likely also thereafter; also see Chapter 6.

2.5.3 Regional Opportunities

In addition to the policies discussed above, Iran has the opportunity to become a major energy trader in the region. The collapse of the Soviet Union has led to the establishment of independent states in the Caspian Sea region, which have significant oil and gas resources. Kazakestan, Azerbaijan, and Turkmenistan offer the opportunity to swap energy with Iran.

When the rush of the investing companies to the region first started the only matter of concern for these companies was to sign a production sharing agreement. The problem of transportation of the oil and gas from these landlocked countries to the world market was not of immediate concern. Now that oil and gas have been found, the problem of transportation to the market has become important. If the decision on the optimal route could be limited to the evaluation of the parameters that have a direct impact on the technical and economic feasibility, the problem could be solved easily. Transportation via Iran, given its large energy infrastructure, would be the optimal solution.

However, this problem is more of a political nature and under the circumstances, the techno-economical aspects of the problem seem to have no bearing on the decision regarding the route selection. Under the USA's Iran-Libya Sanction Act (ILSA) it is difficult to implement the most economical solution. For example, the USA backs the construction of the Ceyhan pipeline with a capacity of one million barrels per day, which is approximately 1,038 miles long (281 miles through

Azerbaijan, 135 miles through Georgia, and 622 miles through Turkey). Construction costs are estimated to be between US$ 2.8 billion and US$ 4.0 billion. Construction on the Turkish section of the pipeline started mid 2002, and the pipeline is expected to be finished late 2004. Without the backing of the USA, this pipeline would be uneconomical and was therefore criticized by many.

In case the sanctions against Iran would be lifted, or other countries would ignore them, Iran has the necessary capability to offer a number of solutions for the transportation of oil and gas from the landlocked regions (Nematollahi, 2000):

- Iran can act as a safe transit corridor for oil and gas pipelines to the world markets with a competitive transit fee.
- Iran can directly purchase oil from these countries (up to 800,000 barrels per day) for its oil refineries in the north of Iran.
- Having the necessary infrastructure, Iran can enter into swap agreements with these countries, receiving oil in the north, at Neka, south east of the Caspian Sea, and delivering equal volumes of Iranian oil for export at the Persian Gulf.
- Having an increasingly integrated gas pipeline network, Iran can purchase gas from Turkmenistan and Azerbaijan for consumption in its northern provinces and/or for export to Turkey, rather than transporting gas from its own gas fields in the south, thereby saving energy and investment costs.

The region is known for its many national and international political problems. Therefore, once production is on stream, the landlocked countries in the Caspian region will want to diversify their export routes to guarantee security of supply to their customers. In that case Iran can benefit when offering economical routes, with good infrastructure, and a sound knowledge of the oil business.

For this study it is important to remember that Iran already delivers gas to Turkey and utilizes gas from Turkmenistan in the north. Furthermore, Turkmenistan uses the Iranian gas infrastructure to deliver gas to Turkey also.

2.6 Conclusions

Demographically a large percentage of young people, high population growth, fast urbanization, and a high rate of unemployment characterize Iran. Economically, a low rate of GDP growth (with an even lower growth rate of productivity), a decreasing share of investment, and an increasing share of consumption expenditure characterize Iran. The government sector in Iran is large by any standard, and the government controls all major economic activities, resulting in slow decision making.

The export of oil is by far the most important revenue raiser and plays a vital role in Iran's economy. In 1998 the share of oil revenue in dollar export, government budget, and gross value added was 75.7, 30.8, and 15.6 percent receptively.

Iran is endowed with rich energy resources. Iran's proven oil reserves were about 86.4 billion barrels in early 1999, resulting in a production-reserve ratio of about 60 years. Iran's natural gas reserves are about 24.3 trillion cubic meter or 857 trillion cubic feet. This is equivalent to 148 billion barrel of crude oil, and the production-reserve ratio is about 160 years. Iran has a large potential of other energy resources also.

The domestic demand for crude oil has grown to 1.21 million barrels per day in 1998. The average annual growth rate of domestic supply of oil for 1977-1998 has been about 4.2%, much higher than the average rate of growth of the real gross domestic product, which was only 1.2%. However, the share of oil in the domestic energy basket has come down from 82% in 1977 to 57.6% in 1998. This reduction in share was mainly due to the gas for oil substitution policy, which is already in place for some time now. The average annual growth rate of natural gas consumption during the period 1977-1988 was 11.3% and the share of natural gas in total energy consumption has grown from 10.1% in 1977 to 40.1% in 1998. Despite the increasing share of natural gas in Iran's primary energy basket, the share of oil consumption in total energy consumption is still high.

Iran's energy transformation and transmission sectors are characterized by increasing losses and own use, which increased 7.1% annually. Considering the sectoral structure of energy consumption, the greatest consumer of final energy is, with 35.5%, the Residential & Commercial sector, while agriculture has lowest share (5%). Furthermore, the Residential & Commercial sector also experienced the highest growth rate of all sectors.

The growth rate of final energy intensity was on average 5.3% over 1974-1998, which is much higher than the growth in real gross domestic product. Given the fact that Iran's energy intensity is high, this indicates a misallocation of energy resources. This trend is also in strong contrast to other countries, which show a decrease in energy intensity.

One of the main reasons for this is another characteristic of Iran's energy sector: extremely low domestic energy prices. The average nominal price of petroleum products in 1998 was 16 Rial or 1.3 US$-cent. For comparison, the price of premium leaded gasoline in OECD Europe was 89.7 US$-cent in 1999, but only 4.2 US$-cent in Iran.

Due to low energy prices, and as a result a high level of energy consumption, the implicit subsidies on final energy consumption amounted to a staggering 14.4 billion US$ in 2000. And even in 1998, when oil prices were extremely low, total subsidies were 9.3 billion US$. The implicit subsidies are between ten and fifteen percent of the total gross domestic product.

The policy intentions of the Iranian government are upward adjustment of energy prices, profit based decision-making in the state-owned energy companies and in the long-term liberalization (and possibly privatization) of parts of the energy sector, especially downstream and non-core activities. Conserving petroleum products and increasing the efficiency of energy consumption, as well as the continuation of the gas for oil substitution policy, are also part of Iran's policy intentions. However, until now most of the good intentions remained intentions and were not translated into actual policy.

Meanwhile, Iran is a member of OPEC and its production capacity is decreasing, so the quota and the production capacity need serious consideration in mid and long-term economic planning.

In general, Iran has to improve its economic performance, which is lagging behind in comparison to other countries. Executing cost effective conservation programs in the light of OPEC quota and production limitations, and continuation of the natural gas substitution policy are required to keep Iran's share in the international oil markets. This in turn will provide enough hard currency revenues to fund the improvement of the economy. Domestically a number of measures are required to support such a policy, among which (i) reduction of the losses in the energy transformation and transmission sectors as well as in the final demand sectors, (ii) correcting domestic energy prices to prevent misallocation of resources, and (iii) improving decision-making by the domestic energy sector. Unfortunately, the actual policy decisions taken so far, which have led to a continued reduction in real energy prices, are once again at odds with the policy intentions.

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Chapter 3

World Energy Outlook

3.1 Introduction

The previous chapter analyzed Iran's domestic economy and especially the role energy plays in it. For Iran, as oil exporting country, the expected long-term trend (2000-2020) in international energy demand in general, and oil in particular, is very important. In this chapter, we analyze the long-term expectations for the international oil market, this to guarantee that the international demand for oil will be large enough to absorb Iran's oil export. The most important long term threat for Iran's oil export seems to be the international efforts to limit greenhouse gas emissions.

The international efforts to limit greenhouse gas emissions have resulted, among others, in the Kyoto protocol. These efforts could have a negative impact on oil exports, and thus on (OPEC and non-OPEC) export revenues. Under the Kyoto protocol, developed countries have to reduce their energy intensities to keep emissions restricted, and many countries have plans and programs to achieve this goal. This downward trend in oil demand is most likely counterbalanced by strong economic growth in developing countries, whose demand for oil and other fossil fuels is increasing.

We will not develop our own predictions or scenarios for the world energy outlook, but use those of a few well-known institutes. Our main sources to gain insight into the quantitative and qualitative aspects of future international energy issues are the Energy Information Administration (EIA, 2001), the International Energy Agency (IEA, 2000), the forecasts of the European Union (EC, 1999), and OPEC (1998). Each of these institutions publishes long-term energy scenarios. We will discuss and compare some of these scenarios and the assumptions used. We mainly want to know if the expected future international oil demand will be sufficient to guarantee oil producers, and especially Iran, sufficient export opportunities.

For Iran's oil export revenue it is also important to know how energy prices will develop over next twenty years. As we will show real oil prices are expected to show some moderate growth. This will, of course, be affected by demand, and total available reserves and production capacity, which are all highly uncertain. All these aspects need to be reviewed to delineate the current and future energy situation.

This chapter is organized as follows. In Section 3.2 we briefly review long-term economic growth. Section 3.3 discusses energy demand, supply, and the role of reserves. Section 3.4 briefly discusses the resulting trends in energy intensities. Section 3.5 looks at oil price expectations. Section 3.6 draws conclusions.

3.2 Long-term Economic Growth

It is widely known that economic growth and the rate of growth of energy consumption are closely related. For future energy demand in general, and the demand for petroleum products in particular, it is also important to know how this growth is distributed. Although we will not model the world's energy demand it is important for Iran's future oil export to know if the market will be large enough.

As Table 3-1 shows, developed countries are expected to experience lower economic growth rates than the world average, with the exception of the United States and Asia's newly industrialized economies (NIEs). Given the United States' energy policy, especially its low petroleum product prices and its refusal to implement the Kyoto protocol, it is reasonable to assume that its demand will remain relatively high.

At the same time, low-income developing countries will experience higher rates of economic growth. Among them, East Asia -especially China- and South Asia -including India- showed high rates of growth over the recent past and are expected to grow by more than 5% annually over the next decade. This economic growth in major developing countries is a major potential for energy demand growth. Note that these countries have a GDP per capita in purchasing power parity that is estimated to be in the range of US$ 3,000 to US$ 10,000, the range in which energy demand explodes due to the rapid growth of the industrial sector and personal mobility (Shell, 2001). This is the range where the income elasticity for energy demand is much larger than one and the demand for transport is rapidly increasing. China's estimated GDP per capita in purchasing power parity was US$ 3,600 in 2000, therefore clearly in the strong energy growth domain, and for India it was US$ 2,200, which, in combination with an annual growth rate of more than 5%, means that its energy demand will start to grow quickly in six years time.

Table 3-1. Economic growth rate in % of real GDP in 1995 prices in various parts of the world

Area	1981-1990	1991-2000	2001-2010
World	3.2	2.6	2.9
High income countries	3.1	2.4	2.5
United States	3.2	3.2	2.7
Japan	4.0	1.4	2.0
Euro area	2.5	2.1	2.4
Asian NIEs	7.4	6.1	4.2
Low income countries	3.5	3.2	4.5
East Asia and Pacific	7.8	7.2	6.0
South Asia	5.8	5.2	5.3
Latin America and the Caribbean	1.1	3.3	3.5
Europe and Central Asia	3.5	2.3	3.4
Middle East and North Africa	2.4	3.2	3.3
Sub-Saharan Africa	1.7	2.2	3.6

Source: World Bank (2002)

OPEC has developed its own economic growth scenario; see Table 3-2. Their growth rates are lower than those predicted by the World Bank, but nonetheless indicate high growth rates for Asia's developing economies (more than 5% for China). The expected annual economic growth rate of the OPEC countries for the period 2000-2020 is about 4%, which is higher that the predicted world average. But the former centrally planned economies of Europe as well as other developing countries show high growth rates also. Only the former Soviet Union shows a relatively slow growth rate, but this country is self-sufficient in terms of energy.

Although OPEC's forecast is less optimistic than that of the World Bank (Table 3.1), both studies show considerable growth in those areas of the world where the demand for commercial fuels is currently low and still has to develop. Furthermore, many developing countries are not hampered by the Kyoto protocol, because their demand for fossil fuels is only just taking off.

As stated before, we will not estimate future energy demand based on expected economic growth. As shall be shown in the next section, many better equipped institutions publish energy demand forecasts that can be used. Here the goals is to show that the demand for petroleum products is not likely to decrease during the next twenty years, which is the time horizon of this research. But as we will show, it is reasonable to assume that also a considerable world market for petroleum products will exist. Next, several long-term energy demand and supply scenarios will be reviewed.

Table 3-2. Average real GDP rates, % in the reference case

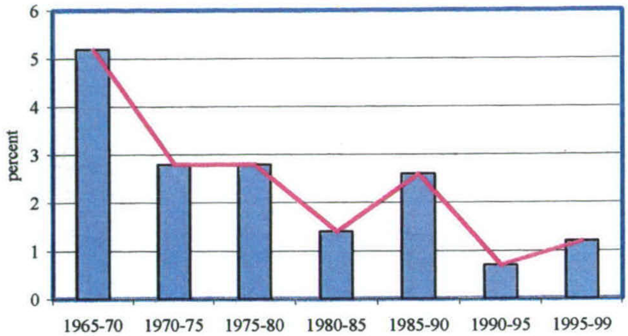
Regions	2000-05	2005-10	2010-15	2015-20	2000-20
OECD	1.9	2.2	2.0	2.0	2.0
North America	2.0	2.3	2.1	2.0	2.1
Western Europe	2.2	2.3	2.1	2.0	2.1
OECD Pacific	1.2	2.0	1.8	1.8	1.7
OPEC	3.9	4.0	4.0	4.0	4.0
South Asia	2.5	4.0	4.0	4.0	4.0
South East Asia	5.4	5.3	5.0	5.0	5.2
China	6.6	6.1	5.6	5.0	5.8
Africa and Middle East	3.5	3.4	3.4	3.4	3.4
Latin America	3.3	4.0	3.7	3.7	3.7
Oil Exporting Countries	3.3	4.0	4.0	4.0	3.8
Total Developing Countries	3.9	4.4	4.3	4.3	4.3
Former USSR	4.0	3.2	2.8	2.5	3.1
Other Europe	4.1	3.7	3.3	3.3	3.6

Source: OPEC (2002)

3.3 World Energy Demand and Supply

Due to technological improvement and environmental concerns, the growth rate of global commercial energy demand has been decreasing over the last few years. Figure 3-1 shows that in recent years the average annual growth rate of commercial energy has fallen to under 2% per annum.

The combination of energy carriers in the world's primary energy basket has changed also; see Figure 3-2. Although the share of crude oil in the world's primary energy consumption is still high (40% in 1998), the shares of natural gas and nuclear energy have increased sharply since the eighties to 23.8% and 7.4% respectively. Because the large unused natural gas reserves, and the fact that the use of natural gas is less damaging to the environment, it is expected that the substitution of crude oil and coal by natural gas will continue.



Source:BP 1992, BP1997, BPAmoco 2000.

Figure 3-1. World primary energy consumption growth rates

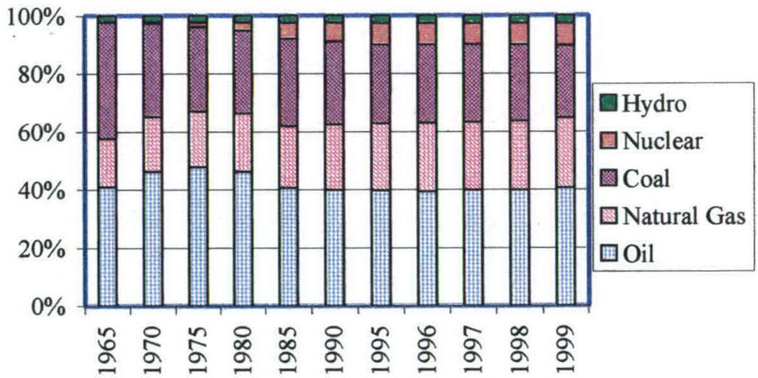


Figure 3-2. World primary energy consumption

In particular the IIASA (Huntington, 1999), the EIA (2001), and other studies expect the replacement of petroleum products (and coal) by natural gas to continue, especially when the emission targets of the Kyoto protocol[1] are taken into account.

[1] The Kyoto Protocol is an agreement that legally binds industrialized countries to reduce their collective emissions of six greenhouse gasses to 5.2% below their 1990 levels by 2008-2012. This 5.2% reduction in total developed country emissions has resulted in differentiated targets for the various countries. The protocol states that the OECD Countries, except Mexico, Korea, and Turkey plus Russia, Belarus, and the countries of Central and Eastern Europe will cut their greenhouse gas emissions by at least 5 percent relative to the 1990 emission level.

The emission restrictions affect the energy sector that has to use less polluting energy carriers. This can be achieved trough several policies. In most industrialized countries taxes on fossil fuel consumption typically take the form of excise duties and taxes that add up to 70 percent of the consumer price (Noord et al., 1999). The tax level on less emitting fuels, such as natural gas, is generally lower. This results in an increase in the demand for natural gas at the expense of oil products. Although less than in Europe, a shift towards natural gas also characterizes the energy mix in the United States (EIA, 1999).

According to OPEC (1998), the Kyoto targets have important implications for the oil market. With oil prices remaining firm, world oil demand will be 9 million barrel per day (bbl/day) lower by 2010 compared to the scenario without Kyoto. This implies an average annual growth in oil demand of less than half the growth expected in scenario without Kyoto. This reduction in demand growth translates, according to OPEC, into an expected loss in OPEC export revenues of almost US$ 16 billion each year up to 2010 compared to the scenario without Kyoto. The impact upon OPEC's export revenue after 2010 will be even larger.

Oil and gas reserves

Studies on global crude oil and natural gas reserves show that in 2000 about 146.4 trillion cubic meters of natural gas was extractable, based on current technology; see Table 3-3. This is estimated to be sufficient for 61.9 years of world demand. Proven crude oil reserves were 1,033.8 billion bbl, which is sufficient for about 40 years of current world demand, again using current technology and production level.

As shown in Table 3-3 the largest known oil and gas reserves are located in the Middle East. About 63.8% of world's oil reserves belong to the five countries of Persian Gulf area i.e. Saudi Arabia, Iraq, United Arab Emirates (UAE), Kuwait, and Iran. The Russian Federation has 32.9% of the world's extractable natural gas reserves and Iran 15.7%, so together they own almost half the world natural gas reserves.

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emission level. For the European Union and Switzerland a target of 8% was agreed upon, and 6% for Canada, Hungary, Japan and Poland. Russia, New Zealand and the Ukraine are to stabilize their emissions, while Norway may increase emissions by up to 1%, Australia by up to 8% and Iceland 10%. The United States had a target of 7%, but the Bush administration does not want to comply with the Kyoto targets and has introduced a different policy that may in the end jeopardize the entire agreement.

Table 3-3. Proven Oil & Gas Reserves in the world and Middle East, early 2000

Oil reserves	Billion barrel	R/P ratio	% of world
Total world	1033.8	41.0	100%
Of which: OPEC	802.5	77.4	77.6%
Non-OPEC[1)]	165.9	13.6	16.0%
OECD	85.6	11.8	8.3%
Total Middle East	675.7	87.0	65.4%
Saudi Arabia	263.5	87.5	25.5%
Iraq	112.5	>100	10.9%
U A E	97.8	>100	9.4%
Kuwait	89.7	69.9	8.7%
Iran	96.5	>100	9.3%
Oman	5.3	15.9	0.5%
Qatar	3.7	14.7	0.4%
Yemen	2.5	12.3	0.3%
Syria	4.0	27.9	0.4%
North America	63.7	13.8	6.2%
South & Central America	89.5	37.7	8.6%
Europe	20.6	8.3	2.0%
Former Soviet Union	65.4	24.2	6.3%
Africa	74.9	28.2	7.2%
Asia Pacific	44.0	16.3	4.3%
Natural gas reserves	**Trillion m^3**	**R/P ratio**	**Percent of total**
World	146.43	61.9	100.0%
Former Soviet Union	56.70	81.8	38.7%
Middle East	56.70	81.8	38.7%
Africa	11.16	98.2	7.7%
Asia Pacific	10.28	40.4	7.0%
North America	7.31	10.0	5.0%
South & Central America	6.31	66.2	4.3%
Russian Federation	48.14	82.7	32.9%
Iran	23.00	>100	15.7%

Source: BP (2000)
[1)] Excludes the former Soviet Union

On the supply-side it is expected that the role of OPEC in the world's oil supply will increase, due to a relative decline in oil production outside OPEC. Table 3-4 contains IIASA's forecasts of OPEC and non-OPEC oil production up to 2020. OPEC's market share will increase from 39.6% to 51.2%, with total oil production estimated at 100.7 million barrel per day in 2020 in OPEC's reference scenario.

The Energy Information Administration's energy forecast also shows that OPEC, and especially the Persian Gulf region, will play a fundamental role in the future of world oil supply (EIA, 2000). As Table 3-5 shows, oil production capacity in the Persian Gulf countries is expected to be in the range of 41 million bbl/day (high price scenario) to 61 million bbl/day (low price scenario) in 2020. The share of Persian Gulf countries in total oil production capacity is expected to be between 36% and 47% in 2020, indicating its importance for the world oil market. Furthermore, OPEC's market share is expected to increase from 44.5% in 1996 to between 49% and 59% in 2020, depending on the oil price scenario used.

Table 3-4. OPEC's world oil production outlook in million bbl/day (Reference Case)

Region	1995	2000	2010	2020
OECD	21.0	22.8	20.8	19.0
North America	14.1	14.8	13.5	12.5
Western Europe	6.3	7.3	6.7	6.1
OECD Pacific	0.7	0.7	0.6	0.4
DCs excl. OPEC	9.5	11.4	12.5	13.4
Total former CPEs	10.2	11.4	13.3	14.8
FSU	7.0	7.7	9.4	10.4
China	3.0	3.4	3.6	4.2
Other Europe	0.3	0.3	0.3	0.2
Processing Gains	1.4	1.5	1.8	1.9
OPEC	27.7	30.7	41.9	51.6
Non- OPEC	42.2	47.1	48.4	49.1
Total World	69.9	77.8	90.2	100.7
OPEC Market Share in %	39.6	39.4	46.4	51.2

Source: OPEC (1998).

Table 3-5. World oil capacity by region and country

Region/Country (MBbl/day)	History	Projection					
	1996	2000		2010		2020	
		LOP[1)]	HOP	LOP	HOP	LOP	HOP
Persian Gulf	20.9	23.2	20.9	35.2	23.2	61.0	41.4
Iran	3.9	4.2	3.9	5.2	4.1	7.0	6.3
Iraq	0.6	0.6	0.6	4.2	2.5	8.1	6.9
Kuwait	2.6	3.0	2.6	3.7	2.7	5.5	4.4
Qatar	0.6	0.6	0.6	0.7	0.6	0.7	0.6
Saudi Arabia	10.6	11.8	10.6	17.2	10.6	33.7	18.2
U.A.E.	2.6	3.0	2.6	4.2	2.7	6.0	5.0
OPEC	30.9	34.7	31.5	50.9	36.5	76.3	54.8
Non-OPEC	42.3	46.4	47.9	52.5	56.7	52.4	57.7
Total World	69.5	81.1	79.4	103.4	93.2	128.7	112.5
Shares							
Persian Gulf	*30.1*	*28.6*	*26.3*	*34.0*	*24.9*	*47.4*	*36.8*
OPEC	*44.5*	*42.8*	*39.7*	*49.2*	*39.2*	*59.3*	*48.7*

Source: EIA(2000)

[1)] LOP and HOP stand for low oil price and high oil price scenario respectively.

Note that the various energy outlooks show considerable differences in expected non-OPEC supply (Mitchell, 2002).

Regardless of possible changes in the world's gas and oil reserves or changes in the trend of energy consumption, the Middle East, the Persian Gulf, and Iran will play an important role in the future supply of world energy. Because the Persian Gulf gas reserves are far away from the European and Far East gas markets, gas transportation costs prohibit the export of Iran's natural gas in the near future. This issue is further complicated by the political problems related to transportation via pipelines through surrounding countries and the US embargo policy. Oil is much easier to trade than natural gas. Because the Iranian economy uses oil extensively, substituting domestic oil consumption by natural gas is a better option than exporting natural gas. The oil will then be available for export, using the already installed facilities. To achieve this Iran should continue its gas for oil substitution policy that has clear domestic advantages, as well as environmental ones.

Energy demand outlook

Table 3-6 shows OPEC's reference demand scenario. The global growth rate of energy demand is expected to reach 1.8% during 2000-2010 and 1.5% during 2010-2020, which is lower that the expected economic growth rate. The growth rates of energy in developing and OECD countries will be in the range of 2.5%-2.9% and 0.8%-1.1% respectively.

Table 3-6. OPEC's expected energy demand growth (Reference scenario)

Period	Total world	OECD	Developing Countries	Former CPES[1)]
1990-2000	2.1	1.9	4.8	0.5
2000-2010	1.8	1.1	2.9	2.3
2010-2020	1.5	0.8	2.5	1.6

Source: OPEC (1998).

[1)] CPES stands for Central Planning Economies and consist of China, the Former Soviet Union (FSU), and Eastern Europe.

Overall world oil demand is expected to be 78.8, 90.2, and 100.7 million bbl/day in 2000, 2010, and 2020 respectively. As shown in Table 3-7 average annual growth rate of crude oil demand is 1.5% and 1.1% in 2000-2010 and 2010-2020 respectively. In our opinion OPEC's oil growth scenario, however, is rather low given the expected high growth rates of countries such as China and India (together more than 2 billon people).

The fact that the expected growth rates of energy demand are higher than the expected growth rates of oil demand shows that the world will substitute other energy carriers for oil products. According to OPEC, even developing countries will experience a relative reduction of the share of crude oil in their energy basket; see Table 3-7. These countries will try to reduce their energy intensity by means of improving their technology base and by energy conservation policies (see Chapter 7 also). These policies are supported by emission reduction policies, such as joint implementation and the clean development mechanism. As a result, it is difficult to estimate the future (up to 2020) rate of growth in oil demand in general and in developing countries in particular.

Table 3-7. Average annual growth rates of world oil demand in OPEC's reference Scenario

Period	Total world	OECD	OPEC	Former CPES	Other DCs
1995-2000	2.2	1.1	3.0	2.7	4.6
2000-2010	1.5	0.6	1.8	2.7	2.8
2010-2020	1.1	0.3	1.5	2.1	1.9

Source: OPEC (1998).

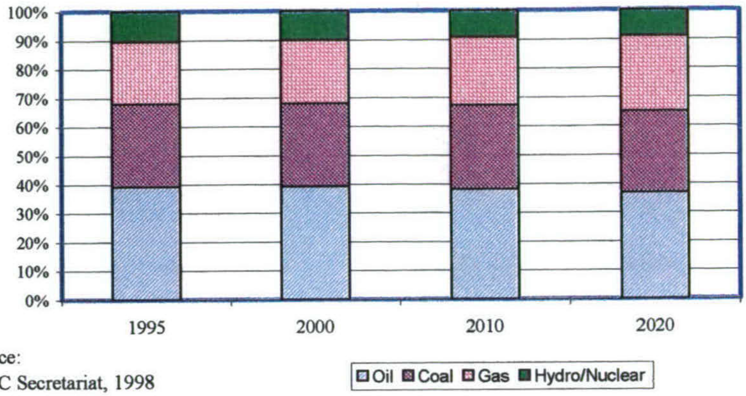
OPEC expects that total world energy demand will be about 231.1 million barrels of oil equivalent (BOE) per day in 2010 and about 267.9 in 2020. The demand of oil will increase from 66.2 million BOE per day in 1995 to 85.6 million BOE in 2010 and is expected to reach to 95.7 million in 2020.

Table 3-8. World energy demand by fuel type (OPEC's reference scenario)

Fuels (MBOE/Day)	1995	2000	2010	2020
Oil	69.6	77.4	90.1	100.7
Coal	50.4	56.3	68.5	77.0
Gas	38.3	43.2	55.5	70.7
Hydro /Nuclear	18.1	19.5	21.6	24.5
Total	173.0	192.7	231.1	267.9

Source: OPEC(1998).

Table 3-8 contains OPEC's forecast of the consumption of all main energy carriers for its reference scenario. As Figure 3-3 shows, the share of oil in total energy demand is expected to decrease from 40.3% in 1995 to 37.6% in 2020, whereas the share of natural gas is expected to increase from 22.1% in 1995 to 26.4% in 2020.



Source:
OPEC Secretariat, 1998

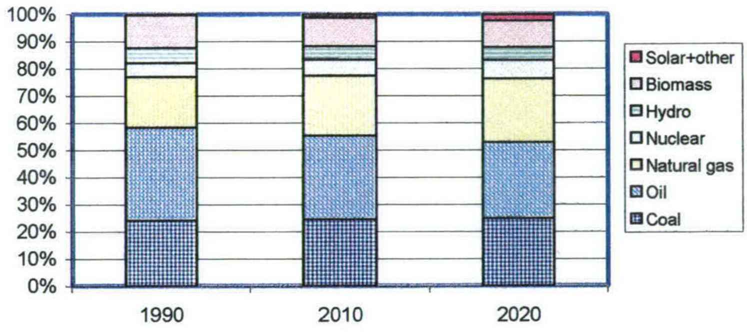
Figure 3-3. Shares of energy carriers in world energy demand

Apart from OPEC, there are several other energy demand scenarios. They all show the same tendencies as the OPEC scenario does, albeit in different proportions. Because of the higher relative carbon content of coal and petroleum products, those two energy sources would be used relatively less, placing more reliance on natural gas and renewable energy, and slowing down the decline in nuclear power. The largest use of petroleum products is in the transportation sector, where there are limited affordable options for fuel substitution.

In his summary of international energy outlooks Huntington (1999) reviews the common elements of these views on energy demand and supply until 2020, which, from a qualitative point of view, are all very similar. The main assumptions are:

1. The fossil-fuel era will remain with us through 2020 and several decades beyond. Oil, natural gas, and coal will continue to grow. Oil use will grow in absolute terms, but lose market share to other fuels. The share of Persian Gulf supplies in total oil will grow over time. The share of natural gas is expected to increase by at least 5% points. Natural gas use will expand, partly to generate additional power in more competitive electricity markets using very efficient technology (combined cycle, etc.), and partly as a substitute for more polluting fuels used in industry.

2. The share of coal will decline further in industrialized countries, but will grow in developing countries such as China and India. The latter are expected to account for almost half of the growth in coal use until 2020.
3. Improvements in smaller, safer nuclear power plants could expand the use of this resource, whereas continued stagnation in this industry could lead to a very large decline. The future of this form of energy, despite the fact that it is CO_2 emission free, is very uncertain, especially since it requires large up-front investments.
4. Contrary to the past, the long-term path for energy prices will increase only slightly faster than inflation, but sudden energy price shocks along the way are likely.



Source: IIASA/WEC, 1998

Figure 3-4. IIASA/WEC's world primary energy mix (Scenario B)

Figure 3-4 shows the world's primary energy mix up to 2020 under the IIASA/WEC scenario B, the middle course scenario. OPEC (1998) expects the share of oil in the world's energy basket to decrease to 37.6% in 2020, whereas IIASA/WEC (1998) expects it to decrease to 27.8%. However, it will remain the most important source of energy and gross oil demand is expected to grow in absolute terms by some 10%. The large difference between the various energy outlooks shows the uncertainty of these forecasts. However, all forecasts differ only is size and composition, but use the qualitative arguments given above to support them.

Excess demand

One should keep in mind the possibility of a gap between demand and supply of oil due to the natural decline of oil production based on the reserve life cycle. There are several experts that consider the production potential of OPEC and the EIA (tables 3.7 and 3.8) much too optimistic. Their estimations show that the world peak production of oil will occur in 2006 (Duncan et. al, 1998). They expect the production level in 2006 to be 31 billion bbl or 87.67 million bbl/day. It will then decline to a level of 23 billion barrel in 2020, which is about 63.01 million bbl per day. If these pessimistic estimates become reality, there will be a large gap between the various oil demand forecasts and oil supply. However, these forecasts of oil supply are based on the Hubbert curve model, which assumes that oil production is a symmetrical curve while in fact it is an asymmetric one (Laherrere, 2000).

These authors assume future technology and new additions to reserves are known. There are many other restrictions to these models too. As a result, these projections should be viewed with care. They believe that we are approaching the "end of cheap oil" and that global production of conventional oil will begin to decline sooner than most other people think, probably within 10 years (Campbell, 1998). However, in the past many of these predictions have been made, but reserves steadily increased. Nonetheless, it is not obvious whether the supply of oil can keep up with demand the next two decades. If so, this will increase the value of Iran's oil reserves. Here we assume that for the next twenty years oil supply will be able to keep up with demand.

Excess supply

There is also an opposite type of reasoning, which argues that oil supply will be larger than oil demand. There are three reasons given for this. First, the average elasticity of energy and real GDP will go down due to a growing service sector and improved end use technology. Second, improvement in technologies will reduce demand and improve supply. Demand is reduced through very efficient natural gas based technologies in electricity production, the further improvement of combustion technology, as well as the development of increasingly cost effective fuel cells. Supply is increased due to the improvements in exploration and exploitation technologies. Third, global warming and ozone layer depletion will cause so much damage that the use of alternative fuels has to be speeded up to prevent an environmental catastrophe. For these reasons Grosse and Yanes (2001) assume that oil demand will reduce much faster than is reported in the various energy outlooks discussed above, and will be no more than 70 million bbl/day in 2020. This causes a large gap between oil supply and demand, resulting in low oil prices. However, as we have argued above, the various energy outlooks take these considerations into account also (Huntington, 1999).

Apparently there is a large difference among experts on the speed with which new technologies are introduced and diffused. Given the current policy in the United States and some other countries on environmental issues it seems reasonable to assume that a faster reduction in the demand for oil products than assumed by the major energy research institutes (EIA, IEA, OPEC) is unrealistic.

3.4 Energy Intensity

A popular way to express the development of energy use is energy intensity, the amount of energy used per unit real GDP. Due to environmental considerations and new energy efficient technologies developed for many different applications, most industrialized economies will continue to shift resources away from the energy-intensive manufacturing sectors that produce basic materials (steel, glass, etc.) to other manufacturing and services. Moreover, within energy intensive sectors there is a continuous search for less energy intensive processes, as well as a shift in materials used. (For discussion of the economic effects of this dematerialization trend see Mannaerts (2000).) As we have seen above this will result in lower growth rates of energy demand than those of real GDP, causing energy intensities to decline further in industrialized economies and result in lower energy growth in industrializing countries.

As was argued before, developing economies will industrialize and will start using commercial rather than subsistent energy resources, raising energy intensities in these emerging countries or, taking into account the fact that they can use more energy efficient technologies from the start, at least show a lower decline than industrialized economies do.

These trends can be observed in the IIASA scenario B (Huntington, 1999). Intensities decline slightly between 1990 and 2020 in the emerging economies, while they decline more sharply in the industrialized countries. However, IIASA expects the energy intensity to grow in the reforming economies (former Soviet Union and Europe), thereby lessening the decline in energy intensity on the world level.

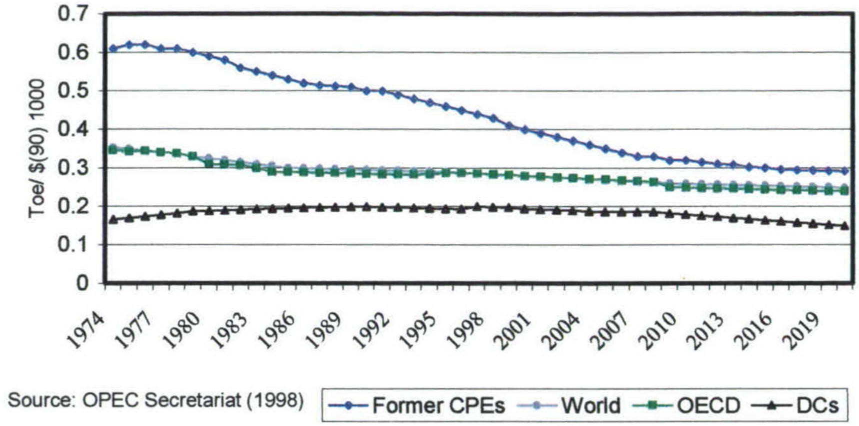


Figure 3-5. Energy intensity outlook

Other studies estimate a downward trend of all energy intensities; Figure 3-5 shows OPEC's view on the world's energy intensities. They expect the former CPEs to show a decrease in energy intensity. In the past developing countries have shown an increase in energy intensity, but it is expected that their energy intensity will decrease in the future also, due to the use of efficient technologies. The figure also shows that the OECD determines the world's energy intensity.

Table 3-9. Energy intensity growth rates in percent per year

Regions/Group	1995-2000	2000-2010	2010-2020
OECD	-1.0	-1.2	-1.4
N. America	-1.2	-1.0	-1.1
W. Europe	-1.0	-1.5	-1.5
OECD pacific	-0.8	-1.4	-1.6
OPEC	-0.8	-1.1	-0.9
Other DCs.	-0.7	-1.1	-1.6
Former CPEs	-3.9	-3.0	-2.3
Total World	-1.6	-1.6	-1.6

Source: OPEC (1998).

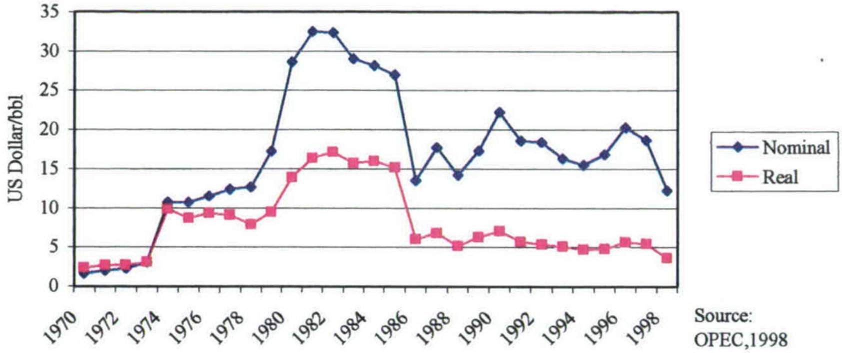
As Table 3-9 shows that in OPEC's reference scenario the OECD energy intensity is expected to decrease at an average rate of between 1.2% and 1.4% per year for 2000-2010 and 2010-2020 respectively. Energy intensity in the former CPEs is expected to improve substantially over the years to come, since the potential for energy efficiency improvements in the FSU and Eastern Europe is large due to high levels of energy inefficiency in the past. Generally speaking, environmental needs, new technologies, and better management will lead to a negative trend in energy intensity around the world.

3.5 The Price of Oil

Normally the price of a commodity is determined by demand and supply, which are each affected by many factors. This is also true for the price of crude oil; see Adelman (2002). However, a structural model for the long term of the price of crude oil is virtually impossible. The appraoch used in the energy outlooks discussed above is the introduction of a growth scenario for the average price, neglecting short term variations. Other approaches to forecasting the price of crude oil for a long time horizon have been investigated (Pindyck, 1999), but are not commonly used. In this study we will make assumptions on the long term development of the international crude oil price which are in line with those made in the energy outlooks discussed above; see Chapter 6. In this section we only review various forecasts published to show the spread in assumptions.

From the early 1950's until the early 1970s the real price of crude oil from the Middle East has been declining steadily. This is due to growing competition from higher output. But also outside the Middle East, production cost were still below the price of oil and already under development in 1972 (Adelman, 2002). After that there was a period of oil price turmoil. This was not due to actual resource scarcity as many assumed, but to the desire by several large oil producing countries to increase their oil income revenue by reducing production. The price increases have, however, lead to a significant decrease in the demand for oil per real dollar GDP and this effect was not reversed when oil prices came down again.

OPEC (1988) has a different view on this subject and concludes that the substantial erosion in the value of the US$, coupled with global inflation and depressed levels of nominal oil prices have resulted in continued lower real values of oil exports. (Also see Shaaf (1985, p 128) on this subject.) The average value of OPEC's reference basket price of $18/bbl agreed upon in December 1986 was worth $15.4/bbl in real terms in October 1988. The composite index, which is the deflator of oil price, decreased to 85.53 in October 1988 from its base value of 100 in December 1986. Figure 3-6 shows the real and nominal oil price based on OPEC calculations.



Source: OPEC,1998

Figure 3-6. Nominal and real price of oil

Cooper (1996) points out that the price of oil in the long run has been largely independent of any particular currency (or group of currencies). But with regard to purchasing power gains and losses of OPEC imports due to changes in the US dollar exchange rate, there have been some losses for OPEC countries, although it is difficult to measure them accurately.

Note that a decrease in the actual value of Iran's oil export income, in combination with an increase in its domestic oil demand, cause the country's real purchasing power to decrease. This is a major threat of the Iran's economy.

The price of natural gas is closely related to the price of crude oil, so fluctuations in crude oil prices affect the price of natural gas. However, due to the high capital cost of the gas infrastructure, natural gas is often traded through long term supply and demand contracts in which the daily spot market price fluctuations play only a minor role, whereas the development of the longer term average price does. This is confirmed by the high correlation between the price of crude oil and the price of natural gas. In the United States, Europe, and the Far-East markets, the linear correlation between the annual crude oil and natural gas prices is 90%, 90%, and 70%

respectively. Figure 3-7 shows the price of crude oil and the price of natural gas for the period 1985-1999.

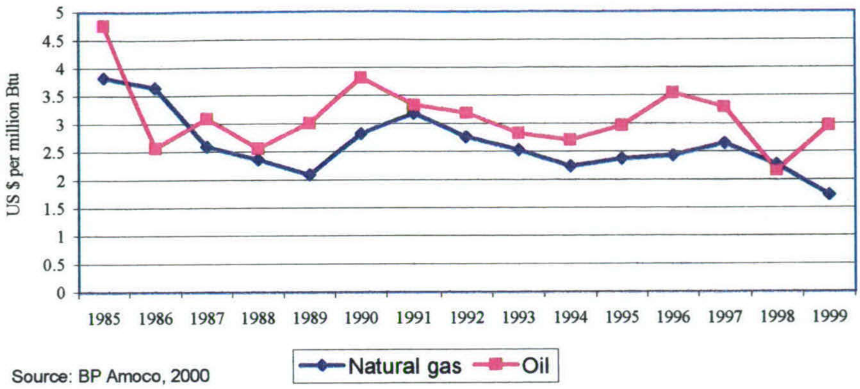


Figure 3-6. Oil (OECD) and natural gas (European Union) prices

We can conclude that the prices of oil and natural gas change in same direction, but that the oscillation of the price of natural gas is less than that of the price of crude oil due to long-term natural gas contracts. The average absolute annual change of price of natural gas within 1985-1999 was 13.6%, where it was 19.2% for the price of oil.

Table 3-10. Various alternative oil price projections

Source	2005	2010	2020
OWEM Reference scenario (1997 US$/bbl)	18.8	20.2	23.5
IIASA/LEW Poll Response (medians), January 1997	-	25.3	28.0
International Energy Outlook 2002 (2000 US$/bbl), Reference scenario	22.7	23.4	24.7
World Energy Outlook (November 2000)	20.4	20.4	27.8
DRI-WFA (October, 2001)	19.4	20.3	23.1
Petroleum Industry Research Associates Inc, October 2001	24.3	24.2	-
The WEFA Group	19.4	20.3	23.1
European Commission, Spring 1996 (1993 US$)	-	29.0	31.0
Median of forecasts other than OWEM	-	20.3	28.0

Source: OPEC (1998) and EIA (2002).

All major energy outlooks expect a moderate increase in real price of crude oil up to 2020. Many studies assume a narrow range of oil prices up to 2020. As Table 3-10 shows, the price of crude oil is expected to be in the range of 23 and 31 US Dollars per bbl in 2020. Note that these are expected average prices, so the short-term volatility that characterizes the price of oil since the early seventies is neglected. In Chapter 6 we will develop our own price forecast.

3.7 Conclusions

For Iran's future oil export, it is important to know if the international market for oil will be sufficiently large. The general view is that the demand for oil will increase in absolute terms, but the share of oil in the world's energy basket will decrease. However, given the demand expectations we can conclude that there will be no limitations for Iran's oil export form a demand side point of view.

Although the ideas about the size of future oil supply and how these will be divided between OPEC and non-OPEC vary, all analyses agree that OPEC's role in supplying oil will increase. So, from the supply side point of view there is no reason to assume that Iran cannot export all oil available. The main conclusion of the demand and supply analysis is that the fossil fuel era will remain with us for the next twenty years and most likely far beyond.

There are several reasons why the demand for oil products will grow less than overall energy demand. For environmental reasons there will be a continued substitution of oil (and coal) by natural gas. Furthermore, technological improvement will reduce the need for oil products. However, a quick replacement of fossil fuel technology and infrastructure by other technologies, hydrogen for example, seems unlikely due to the exceptionally high capital requirements for a new infrastructure, and the fact that the existing infrastructures are sunk cost. On top of that improved oil exploration and exploitation technologies will add to oil reserves and thus the time horizon for a need to change from an oil availability point of view. All researchers seem to agree on the fact that the role of renewable energy will remain small, despite the massive efforts to promote them particularly in Europe.

The highest growth in the demand for oil products, especially for transport, will be from Asian (China, India), Eastern European and the Russian economies as these economies move into the per capita income range (US$ 3,000 to US$ 10,000) in which energy demand grows very fast, even if fuel prices are high. Equally important will be the development of energy institutions and markets in developing countries. The successes of future environmental policy may well depend upon the speed with which efficient technologies are transferred from richer to poorer countries. Currently, this transfer faces a range of obstacles created by weak market structures and inappropriate institutions.

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Chapter 4

Determination of Strategic issues

4.1 Introduction

Iran's economic and domestic energy situation was analyzed in Chapter 2. The international prospects of energy were discussed in Chapter 3. This chapter develops strategies for the Iranian energy sector using a SWOT analysis, where SWOT stands for Strength, Weaknesses, Opportunities, and Threats. SWOT analysis was developed for, and is mostly used by, companies. However, as will be shown, it is a useful tool to analyze the domestic energy policy of Iran also. Based on the approaches proposed for corporate planning and the planning of non-profit organizations, a general approach is formulated to tackle the strategic planning of Iran's domestic energy sector. In this process, strategic planning is initiated by first clarifying the mission for Iran's energy policy. The analyses of domestic and international developments in chapters 2 and 3 provide the necessary materials for extracting the most important strengths, weaknesses, opportunities, and threats. This is then used to identify the strategic issues, from which appropriate strategies can be extracted. These strategies will be the starting point for the policy improvement analysis is Chapter 7.

This Chapter is organized as follows. In Section 4.2 strategic planning and SWOT-analysis are discussed. In Section 4.3 the strategic mission for Iran's domestic energy sector is formulated. Section 4.4 states the opportunities and threats using the analyses of Chapter 2 and 3. Section 4.5 discusses the domestic energy market strengths and weaknesses. Based on the mission and using the results of the SWOT analysis, the strategic issues and main problems of Iran's domestic energy sector are derived. These strategic issues will guide the formulation of strategies in Section 4.6. Section 4.7 draws conclusions.

4.2 Strategic Planning and SWOT Technique

The methodology for this part of the research is based upon the theory of strategic planning. An often used definition of strategic planning is "… a disciplined effort to produce fundamental decisions and actions that shape and guide what an organization (or other entity) is, what it does, and why it does it" (Bryson, 1989, p 5) Another definition is: "Strategic planning is the process of selecting an organization's goals; determining the programs necessary to achieve specific objectives en route to the goals; and establishing the methods necessary to ensure that the policies and programs are implemented" (Bryson, 1989).

In the literature the concepts strategic management, strategic decision-making and strategic planning, are concepts that are not always properly distinguished from one another. What is described as the core of the strategic planning methodology seems analogous to the descriptions of the core of strategic management and strategic decision-making, or even strategic marketing (Bowman and Asch, 1987; Rue and Holland, 1989; Kerin and Peterson, 1993). This is of course incorrect. Mintzberg (1994a) defines planning as a formalized procedure to produce articulated results, in the form of an integrated system of decisions. Furthermore, the mission to be achieved should be clear, since strategic planning aims at achieving this mission, not formulating it.

In the case of Iran, this means that the goals of its domestic energy policy should be clear and in support of the broader goal of optimizing the use of Iran's natural energy resources to the benefit of the country. Here we analyze to what extent past decisions on domestic energy meet the criterion of being integrated with and supportive to the broader policy to optimize the country's benefits from its natural resources.

There have been and still are fierce discussions on what strategic planning is and how it should be executed; see Mintzberg (1994a,b), Ansoff (1994), and Bonn and Christodoulou (1996). Others have worked on how to apply it for government bodies; see Berry (1994), and Barkdoll and Bosin (1997). For the purpose of this research the aspect of determining the correct issues to plan and the consistency between different objectives are important. Therefore, the literature on strategic planning will not be reviewed in detail, since most of the discussions are on how to conduct the planning process in a company and on implementation issues.

Strategic planning should, however, be distinguished from two other kinds of planning i.e. long-range planning and comprehensive planning for cities and regions, which sometimes is labeled long-range community or master planning. For organizations and other entities, like the energy sector of an economy or the economy as a whole, the terms strategic planning and long-range planning are often used as synonyms.

Although most of the theory on strategic planning has focused on firms, there is also literature on how to apply it to the public sector. Strategic planning in the public sector has been applied primarily for military purposes, NASA's space program, and the practice of statecraft on a grand scale (Bracker, 1980; Barkdoll and Bosin, 1997). However, strategic planning can be applied to many other entities too, such as,

- Public agencies, departments, or major organizational divisions;
- General-purpose governments, such as cities, counties, or state governments;
- Non-profit organizations providing basic public services;
- Specific functions, such as transportation, health, or education, that bridge organizational and governmental boundaries.

Herewith the strategic planning methodology will be used for a combination of entities, which are all part of the Ministry of Petroleum, but actually cover one sector of the Iranian economy, domestic energy, since virtually all activities in this sector are under state control; see Section 2.5.

The many schools of thought and models of strategic planning all include the following steps: general policy and direction setting, situation assessment, strategic issue identification, strategy development, decision-making, action, and evaluation (Bryson, 1989). The Harvard policy model of strategic planning in combination with the stakeholder approach may be the best-known approach to strategic planning and this approach is briefly addressed here. This model is based on the general concept of strategic planning which implemented the advantages of all schools of thought in the line of economy and sectors interaction rather than an organization. The Harvard policy model is the principal inspiration behind the most widely cited recent models of public and non-profit sector strategic planning (Bryson, 1989, p. 30). The main purpose of the model is to develop the best strategy, where strategy is defined as "a pattern of purposes and policies". Analyzing internal strengths and weaknesses, and identifying external threats and opportunities, better known as SWOT analysis, can obtain the best strategy. This element appears to be applicable in any organization, private as well as public, and profit as well as non-profit, but it can also be applied to economic sectors or any other entity. Carrying out SWOT-analysis is illuminating; it points out what needs to be done, and it puts problems in perspective. However, SWOT will be a useful tool only if used properly and with sufficient follow-up (Hill and Westbrook, 1997). The main weakness of the Harvard model is that it does not offer specific advice on how to develop strategy, which in turn is needed as input for the strategic planning process.

The stakeholder management approach sees the formulation of a strategy for any entity as building bridges to its stakeholders. Stakeholders are all groups in the entity and in its environment that are affected by or can affect the future of the entity. The stakeholder approach is thought to be especially useful for public entities, because it integrates economic, political, and social concerns (Bryson, 1989, p. 33). For example, if we regard Iran's energy sector as an entity, the domestic energy consumers, policy makers, employees in the energy industries, private owners, local governments, financial institutions, foreign oil and gas consumers, foreign investors, etc. are all stakeholders, and a good domestic energy policy has to take into account the needs of all groups mentioned.

There is, however, a missing step between the SWOT analysis and the development of the strategies, the identification of strategic issues. We add this step in our approach.

The concepts, procedures, and tools from strategic planning be used effectively; see Frentzel, Bryson, and Crosby (2000). In fact, strategic planning embraces a range of approaches that vary in their applicability to the public and non-profit sectors, and can easily be misinterpreted (Mintzberg, 1994a). According to the above, any strategic planning process includes at least the following steps:

- Develop or restate the mission;
- Assess the external environment: opportunities and threats;
- Assess the internal environment: strengths and weaknesses;
- Identify the strategic issues facing the entity under study; and
- Formulate strategies.

Figure 4-1 summarizes this process with respect to Iran's domestic energy sector and relates it to the chapters of this research. The entity for which this analysis is made, is the Iranian domestic energy sector as outlined in Section 2.5. In these steps, the opportunities and threats are the external factors, which are beyond the control of the entity, were reviewed in chapters 2 and 3. The internal factors are those controlled by the entity, which we reviewed in Chapter 2 also. For each of the factors one must ask "...is this an internal strength or weakness, or is it an external opportunity or threat, that makes this of strategic importance?" Listing these factors will become useful in the next step i.e. the development of strategies.

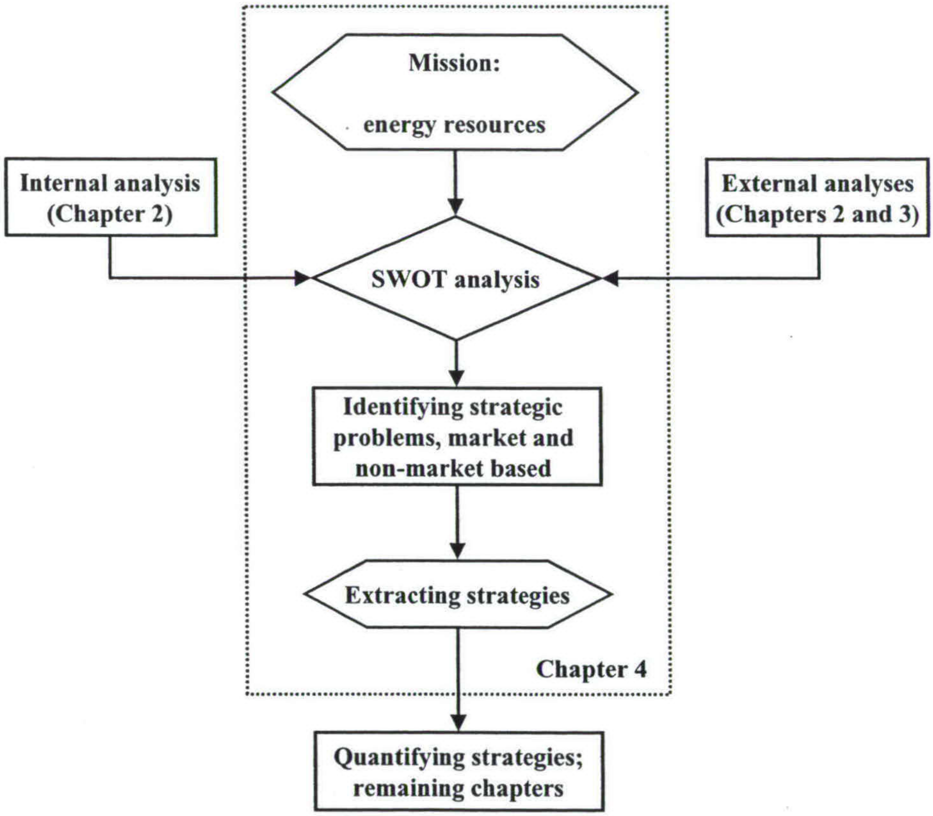

Figure 4-1. Strategic planning process for Iran's energy sector

A strategy is defined as a pattern of purposes, policies, programs, actions, decisions, or resource allocations that together define what an entity is, what it does, and why it does it. An effective strategy must meet several criteria. It must be technically workable, politically acceptable to key stakeholders, and must accord with the entity's philosophy and core values. For example, if a one-time increase of domestic energy prices to European levels would be defined as a strategy, this could be a good policy from an economic point of view, but it would be impossible politically and socially. This would than be labeled as an ideal, but non-effective, strategy.

In what follows the mission of the Iran's energy sector is stated first. Next, Iran's place in the global economic environment is analyzed to reveal the external opportunities and threats the Iranian energy sector faces. An analysis of the current domestic energy policy and the structures of energy supply and demand will identify the strengths and weaknesses of Iran's energy sector in general and the organization of the domestic energy markets in particular. These analyses can then be used to draw up strategies for Iran's domestic energy sector.

4.3 The Mission of Iran's Domestic Energy Sector

The mission of Iran's domestic energy sector as an entity is to promote the efficient usage of Iran's energy resources, where efficient usage means beneficial to the economy. This mission for the domestic energy sector is, of course, part of the mission of the total energy sector. This should be the guiding principle for all parties involved.

Energy resources should be extracted in the light of sustainable development, that is, usage now should result in wealth that also benefits future generations. This mission is based on Iran's 1980 constitution. The Ministry of Petroleum has translated the mission into "... the optimal and scientific extraction of oil and gas resources, as well as the efficient usage of these resources domestically (NIOC, 1987)."

On the basis of this formulation of the mission, this research will analyze the current domestic energy policy using SWOT analysis, and identify strategic issues. The latter will be the starting point for the formulation of ways and means to improve domestic energy use.

Note that many in Iran believe that the wealth of Iran's energy resources is best distributed by making energy available at low prices. What we will show is that this belief is a fallacy and that low domestic energy prices actually lead to a lower GDP per capita.

4.4 International Energy Market: Opportunities and Threats

International energy markets, especially the oil market, were discussed in Chapter 3. Trends in key international issues, such as, energy intensity, energy prices, economic growth, substitution of energy products, the global warming problem, and emerging technologies were discussed. The developments in these areas are beyond Iran's policy reach. One could argue that a complete stop of its oil production would affect international oil prices, but this cannot happen under normal circumstances. Iran has to protect its role as a supplier to the international oil market and a substantial reduction in its oil export would be devastating to its economy. (As is the case for most other oil-producing countries, which no longer have sufficient financial reserves for serious production cuts (Mitchell, 2002).) However, as will be shown, domestic oil consumption may strongly reduce its role as a supplier, since production is limited. Based on chapters 2 and 3 we can identify the following list of opportunities.

Opportunities

1. The average annual growth rate of the world economy is expected to be between 2% and 3% until 2020; see Chapter 3. This will result in continuous growth of global energy demand in general and oil in particular. Therefore, there will be a suitable market for Iran's oil.
2. The annual growth rate of world energy demand is expected to be 1.8% and 1.5% over 2000-2010 and 2010-2020 respectively, indicating a relatively active market.
3. Petroleum products will continue to play a major role in global energy consumption. OPEC expects the demand of oil to be 100.7 million bbl/day in 2020, while coal and natural gas are expected to be 77.0 and 70.7 million BOE per day respectively, indicating oil remains the dominant fuel in the world's energy basket. This is despite the many policies to substitute oil by natural gas and other fuels.
4. The proven reserves of oil and gas in different areas of the world show that the Middle East, and especially the Persian Gulf, will play a major role in the oil and gas market in the future. Although some researchers have high expectations about the potential reserves of the Caspian Sea region, as another North Sea that can compete with OPEC, it is generally expected that the share of OPEC in total

supply will increase. In 2000 the share of the Caspian Sea region and the Persian Gulf region in total proven oil reserves were about 1.8 and 64.3 percent respectively.

5. The OPEC market share in the world oil production is expected to increase to 51.2 percent in the year 2020, and the share of the OPEC Gulf members in meeting global oil demand will, with a forecasted 46%, be dominant.
6. Iran, as a member of OPEC and being located in the Persian Gulf, can keep its role in the international oil market. Iran's contribution to the world's oil production is expected to be approximately 4 million bbl/day, so Iran's contribution to the international markets could be considerable. Note that some researchers claim that Iran's oil production could be as high as 7 million bbl/day, if the latest technologies are used and new reserves are added. In our opinion this is, however, too optimistic; also see Chapter 6.
7. The demand for oil is expected to increase in the future, but natural gas consumption is expected to increase at an even higher rate due to concerns about the environment and new efficient gas based technologies. Iran, as the holder of the second largest gas reserves in world, can play an important role in the future gas market and could become a major supplier for Europe and other regions once Russia is at its peak production. This will, however, materialize at the end of our time horizon at the earliest.
8. Iran's position in the global energy market provides good opportunities to extend its political, economical, and technological relations with other countries.
9. The strategic geopolitics of Iran can make it a corridor for energy trade in the region, assuming political issues can be resolved. The energy swap in the region, especially in the north, can be beneficial for the Iranian economy. Iran can act as safe transit corridor for oil and gas pipelines to the world markets with competitive transit fees and relatively low capital expenditure, since much of the required infrastructure is already available.

Threats

1. In all industrialized countries, especially those under the Kyoto protocol, the decrease in energy intensity will continue. Furthermore, environmental problems will result in high energy and carbon taxes all over the world. Various studies have shown that, in order to achieve the emission abatement as agreed

upon in the Kyoto protocol, the average cost of energy would have to increase. For the U.S.A. this would imply that energy prices in 2010 should be 17 to 83 percent higher than in the non-Kyoto scenario (EIA, 1998). Of course, the Bush administration did not ratify the Kyoto protocol, but the U.S.A. will also have to take measures mitigating energy use. This in turn will lead to an increase in the cost of production and generally some cost-push inflation in developed countries. The inflation imported by oil exporting countries will decrease the purchasing power of each barrel of oil exported (OPEC, 2000).

2. The political problems in the Middle East, especially the Israel-Palestinian and the Iraq problem, are expected to be persistent and possibly destabilize the region even further. Despite the qualification of Iran as a rogue state by the Bush administration, the Iran-US political problem is expected to relax during the next two decades. More importantly, most European governments have openly denounced the US qualification, and Europe is and will remain one of Iran's largest export markets.
3. The lack of financial assistance for Iran, as well as the lack of technology transfer, will delay oil and gas development projects as it has done since March 1995 when the U.S.A., via an executive order, banned foreign investments in the Iranian energy sector. This was one month later replaced by a ban on all U.S. exports to Iran. In 1996 the U.S. replaced the ban by the Iran-Libya Sanctions Act, which was passed to prevent European and Japanese countries benefiting from the US export ban (Fairbanks, 2001).
4. Iran's oil export is expected to decrease in the future, due to an increase in domestic energy consumption, assuming the current domestic energy structure remains in place.
5. The depreciation of the US Dollar against other currencies, along with the increases in the level of inflation of Iran's trading partners, will decrease the real purchasing power of Iran's oil export. Iran has lost much of the real purchasing power of its oil revenue in the past (IIES, 2001a). This will be the case in the future also, and policy makers should be aware of such losses. Note that the Euro can be used to hedge against the US$, and can (partly) offset the possible purchasing power losses.

4.5 Domestic Energy Market: Strengths and weaknesses

In Chapter 2 Iran's domestic energy markets and energy policies were analyzed. This internal analysis contains sufficient information to accommodate the requirements of the SWOT analysis of this chapter. First, the weaknesses of Iran's energy sector are discussed, with special emphasis on the domestic side. Next, the strengths are discussed.

Weaknesses

1. Iran's fast population growth has resulted in a strong increase in direct and indirect domestic energy demand. Although population growth has slowed down in recent years, it is still 1.5 percent per year. The size of the population was 61 million people in 2000, of which 51.2 percent was younger than 19. More people means more energy. Even with a considerable reduction in population growth, the current population pyramid with its broad base will result in many new families and a steady increase in the use of energy appliances and new dwellings, leading to strong increases in energy demand. In addition, every new household consumes energy based on the current consumption structure, which is highly inefficient. Direct energy demand increases through the use of inefficient appliances and the construction of highly energy inefficient buildings.
2. Iran suffers from a shortage of efficient technology. Most of Iran's economic sectors use obsolete and depreciated machinery and facilities; these are far below the standards used in other parts of the world and are certainly not based upon best practices. For example, only four of Iran's ten refineries have a remaining lifetime of more than six years, and the others are obsolete. The same goes for power stations and industrial factories, such as textile mills.
3. The Iranian government is overly involved in the economy in general and on the energy sector in particular. Decision-making is complex, centralized and requires too much government approval, resulting in inefficiency and inflexibility. This causes too much red tape and prohibits efficient decision-making within the energy sector, in particular for the domestic market.
4. The share of the government sector in economic and service activities in Iran is very high. For this reason energy consumption in the public sector is high also.

The government is consuming about 49.2% of total domestic energy supply in Iran (IIES, 1995). (Energy conservation programs could be initiated in the governmental sector.) In addition, the government owns about 99% of Iran's energy producing companies (production, transmission, and transformation), and most of the supply companies. For the time being and due to the low level of energy prices in Iran, conservation projects cannot be justified on the basis of a financial cost-benefit analysis. However, based on the opportunity cost of energy carriers, a social-economic cost-benefit analysis justifies the same projects. Some of the possibilities are:

For refineries

- Reduction of losses and fuel use;
- Producing petroleum products on the basis of international standards with an acceptable quality;
- Development of refining processes that produce more high value products;
- Extraction of wet hydrocarbons (such as C4+) from natural gas and as a result the supply of more dry gas; and
- Reduction of losses in the transportation systems (including pipelines).

For power generation

- Improving the efficiency of existing power generation plants;
- Investing in new technologies, such as, Combined Heat and Power (CHP);
- Reduction of losses in transmission and distribution of electricity through improvement and installment of an efficient grid;
- Substitution of petroleum products as a fuel by natural gas;
- Increasing the share of hydro electricity; and
- Diversifying the electricity supply via completing the first phase of the Booshehr nuclear power plant or stopping the project, to prevent the continued waste of capital.

For governmental industries

- Applying compulsory energy auditing;
- Replacing non-efficient technologies by efficient ones; and
- Peak load shaving management during the day and during the year.

For construction

- Developing and applying compulsory building codes;
- Restructuring current buildings to conserve energy; and
- Restricting the utility budget of large governmental buildings (especially energy costs) in order to encourage energy conservation.

5. Continued urbanization due to better infrastructure and higher income levels in urban areas. The share of the urban population grew from 38% in 1966 (9.8 million) to 62% in 1997 (37.7 million). Urban households tend to use more energy than rural ones. Furthermore, this type of population growth requires more energy for public buildings, passenger transport, and transportation of goods, which in turn increase the demand of energy.
6. There is a lack of reliable information on energy issues. The lack of a centralized and powerful data bank containing reliable information about supply and demand is an important problem when formulating energy policy. A good databank would allow better planning by government bodies and entities at all levels, as well as energy users and suppliers. Experiments in other countries show that correct and adequate information can increase energy efficiencies by 10 to 15 % in comparison to the situation where reliable information is lacking (IIES, 1995).
7. The lack of an effective energy pricing mechanism. For a long time Iran's nominal energy prices have been fixed whilst, due to high inflation, real energy prices have been diminishing. This governmental pricing policy has resulted in serious misallocation of resources and increasing energy intensity. Low energy prices also made energy conservation projects financially unattractive. This is a major weak point in Iran's energy policy. Energy prices should be based on a suitable and comprehensive energy-pricing rule, e.g. be based on the opportunity cost of energy.
8. Due to Iran's (lack of) energy pricing policy, a high level of implicit energy subsidies exists. Based on border prices they amount to between US$ 10 and US$ 15 billion per year, depending on international energy price development. For some years, they even amounted to the level of oil export revenues.
9. The high level of implicit subsidies not only gives the wrong incentives to energy consumers, it reduces government income also. Because of this lack of government income, the government uses money supply to make ends meet. The

high growth in money supply again induces inflation, which reduces the real income of the Iranian people. This mechanism also makes it more and more difficult to induce non-oil economic activities.

10. There is no incentive for good energy management. Energy management in Iran is virtually absent and there is insufficient regulation and regulation enforcement in this respect. This has lead to a repetition of mistakes in decision-making, and the continuation of inefficient practices. In many situations, it is unclear who is responsible. These are important causes of the domestic waste of resources, in particular energy resources. Many government bodies take decisions on energy issues, among which, the Ministry of Energy (responsible for power, hydroelectricity as well as fossil fuel electricity), the Ministry of Petroleum (responsible for oil and gas), the Ministry of Industry and Mining (responsible for coal), Iran's Atomic Organization (responsible for nuclear and renewable energy), Jihad-agriculture ministry (responsible for rural electricity), and finally the Energy Commission of the Majlis, the Iranian parliament. Co-ordination of energy policies between these entities is virtually absent. This weak point could be removed via restructuring the organization of the energy sector. Currently the establishment of the Energy Supreme Council is supported by different studies (IIES, 1995, 2001b) to cure this weak point. This council's task would be to co-ordinate the policy efforts.
11. The oil and gas industry under the responsibility of the Ministry of Petroleum and the many oil and gas related companies that are its responsibility is not organized effectively. The ministry is well aware of the many problems and tries to resolve them through restructuring and redistributing responsibilities towards the companies (NIOC, 1999). However, until now these efforts have been insufficient.
12. The Iranian economy is dominated by the oil and gas sector. The development of this sector has been at the expense of other sectors, which failed to develop or even shrank. This development based on one commodity makes the Iranian economy vulnerable. This one commodity relation between the national and the international economy has imposed losses on the economy through the oscillation in the level of oil revenues and the effect thereof on the government budget (Amirmoeni and Mazraati, 1999). This weak point is currently addressed somewhat by the establishment of a Stabilization Fund, which will be fed by oil

revenue in excess of what was expected, to meet the needs in times when revenue is below what was expected. However, a more comprehensive diversification policy is required to improve Iran's economic structure.

13. The technology used in Iran's energy sector is old fashioned and obsolete. This needs to be improved to boost the lifetime of Iran's reserves, and to improve the efficiency of Iran's domestic energy sector.
14. Incentives to replace inefficient appliances by efficient ones are lacking, especially for household appliances. Reducing energy use and as a result energy costs, will certainly not be an incentive under the current low energy price regime. But even when replacement is due, the financial benefit from energy cost reduction by using energy efficient appliances, which works in, for example, European countries, does not work in Iran due to very long pay back periods.
15. The low energy prices also lengthen the use of facilities and equipment that would otherwise be economically obsolete. Because of the low energy running costs, machinery, equipment, cars, and housing facilities are used beyond their normal lifetime and use more energy than is efficient from a social-economic point of view. As a result managers in private and public entities are not receptive to energy conservation issues.
16. The absence of standards and regulations. Because standards and regulations are virtually absent in, for example, the construction of houses and commercial buildings, a major part of the energy used is lost. (Note that in Iran large changes of temperature between summer and winter occur.) Another example; in Iran the average consumption of gasoline in cars is 12 to 14 liters per 100 km. In other countries, this consumption is much less. The same can be found in other economic sectors; such as steel and aluminum industry (IIES, 1995).
17. The incoherent and inconsistent economic strategy at the macro level results in counterproductive developments between sectors, especially between the energy sector and other parts of the economy. Energy authorities are trying to decrease the energy intensity of industries, while new developments of these industries set up by other ministries are not energy efficient. Iran is in the early stage of industrial development, so heavy industries are on the top of the development agenda, which are incidentally the industries that are disappearing from the industrialized countries (EIA, 2000). In Iran the combination of economic

activities is not changing towards energy extensive activities, as is the case in most other countries, where energy extensive activities are a considerable part of the GDP.

Almost all of the above mentioned weaknesses are under the control of Iran's policy makers, so they can be removed or changed when there is sufficient political support.

Strong points

Iran has the following strong point as well.

1. Due to its large natural gas reserves Iran can easily substitute oil with other energy sources, especially natural gas. The oil replaced by natural gas can be exported. (Because of its liquid form, oil is easier to export than gas.) This policy also results in a reduction of Iran's contribution to global warming. Since Iran's natural gas reserves are about 15.8% of world reserves, and 1.7 times more than its proven extractable oil reserves, there is ample opportunity. Existing facilities can be retrofitted to natural gas also.
2. Iran is strategically located. It has access to the Caspian Sea in the north and the Persian Gulf in the south, and the historical Silk Road passes through it. It also borders several land locked countries that have energy resources that can be exported. Iran can act as a transit station for these countries. Furthermore, there is the possibility of energy swaps. For example, due to the variation in weather conditions and the time difference of different parts of Iran and the neighboring countries, electricity swaps for peak load management can be arranged.
3. Iran can buy oil and gas from its northern neighbors and swap it with its southern products, saving the transport cost of the oil and gas. Iran has the capability to be an intermediate for the export of oil and gas from the wider region. Iran can act as safe transit corridor for oil and gas pipelines to the world markets with a competitive transit fee. Having the necessary infrastructure, Iran can enter into swap agreements with these countries, receiving oil in the north, at Neka, south east of the Caspian Sea, and paying them with equal volumes of oil at the Persian Gulf, which can be exported to the world markets. Having an extensive gas pipeline network, Iran can purchase gas from Turkmenistan and Azerbaijan for consumption in its northern provinces and/or for export to Turkey, rather than transporting gas from its gas fields in the south.

4. The availability of potential natural gas markets in the east (Pakistan and India) and the west (Turkey and the European countries).
5. The policy to replace petroleum products by natural gas. This policy already makes it possible to export more oil with the current installed facilities. The domestic market for natural gas, integrated with the neighboring countries, should be developed further.
6. Expansion of liberalization and private ownership, and the prevention of further expansion of the government. Iran has already experienced that the continuous expansion of state-owned enterprises is a non-successful and uneconomic way to expand. This has resulted in very low efficiencies in all state firms, enterprises, and organizations. Misallocation of the resources in state-owned activities is a well-known phenomenon in Iran. Paring down of the government sector, especially in the energy sector, would help to improve the efficiency of these activities nationwide. Well-defined liberalization and privatization of state-owned firms is required.
7. The Iranian government is aware of the fact that a system of good standards and regulations is needed. This can be considered as a strong point. Establishment of a system for energy auditing and cost accounting will make the energy systems more sensitive to energy saving issues. Experiences of other countries show that 10 to 20 percent cost reductions can easily be achieved with a productive energy auditing system.
8. The execution of training courses in energy management. There are governmental and private entities that are capable to transfer knowledge on energy management and technology to the individual users, households, factories, etc. for energy auditing and conservation programs. These entities are under the authority of the Ministry of Energy and the Ministry of Petroleum.

4.6 Strategic issues

Based on the above analyses the following strategic issues of Iran's domestic energy sector can be determined:

1. Reduction of energy intensity. As our analysis shows, Iran's domestic energy use is not based on good practice, and energy intensity is high compared to the level and structure of economic activity.

2. Improving the technology base. The technologies used in Iran are outdated and urgently need to be updated to improve the efficiency of all economic sectors, especially the domestic energy sector.
3. Improvement of decision making in the energy sector. The organization of the energy sector and the structure of decision making needs to be revised. Without such a revision, it will be hard to improve the sector.
4. Paring down of the role of the government. The energy sector is completely controlled by the government. The government entities have roles as regulator, decision maker, executer, and entrepreneur throughout the sector. This has lead to inefficiencies and paralyses energy sector improvement via red tape procedures and slow decision-making.
5. Reserves are depleting, resulting in declining oil production. Most reserves are over their peak production. Without new investments and improved technology, Iran will not be able to keep up oil production at its current level.
6. OPEC quota. Since the quota covers all production, it needs to be reviewed in the light of domestic energy consumption development and production capacity decline.
7. International political issues. These play an important role for future energy sector development, and the role Iran can play as an energy producer and, given its location, as an energy broker. Especially the U.S. sanctions policy needs to be addressed.
8. Energy pricing mechanism and the related subsidies. As the analysis shows, improving the domestic energy pricing policy is an important prerequisite for improvement of the domestic energy sector.
9. Energy conservation. Improvement of the pricing policy is not enough to address this issue. Better regulation and the introduction of standards and energy labels, such as energy construction requirements for buildings, energy tags for appliances, etc., are called for.
10. Natural gas reserve utilization and oil by gas substitution. Given the large gas reserves and the fact that oil is easier to trade than natural gas requires a continuation of the gas for oil substitution policy.

These strategic issues can be grouped into three main categories. First, energy intensity, technology improvement, energy pricing and subsidies, non-price energy policies fall into the category of *energy conservation*. Second, natural gas reserve abundance, reduced oil production capacity, and the OPEC quota restriction can be categorized as *natural gas for oil substitution*. Third, the improvement of decision-making and the paring down of the government sector fall into the category of *improving decision-making within the government*, and the *liberalization and privatization* of now government owned energy entities. Note that the international political issues (no. 7) affect all three categories and that it is beyond the scope of this research.

Of course, the categories are not independent. For example, an improved pricing policy will result in the substitution of oil products by natural gas, but complemented with efficient decision-making such a policy will be more effective. The international and domestic energy market issues mentioned above show that Iran could continue to play its role in the international energy markets, because it has oil and gas reserves and the infrastructure to export these. This requires, however, a reduction in the growth of domestic oil consumption. On the basis of the three strategic categories identified, Iran should develop the following three broad strategies:

1. Further development of the domestic natural gas market and continued replacement of petroleum products by natural gas wherever economically feasible.
2. Development of a comprehensive energy conservation policy. The conservation policy requires, among others, a well-defined energy pricing policy, the establishment of energy standards, compulsory restrictions of, and codes for, energy use.
3. Iran's domestic energy sector needs to be reorganized to improve decision-making. The government institutions should be improved. For the now state owned enterprises in the domestic energy sector, liberalization and possibly privatization should be the leading principles.

These three strategies need to be translated into policies. Execution of these policies will improve Iran's energy basket. It is clear that these strategies require many issues to be resolved and the application of many instruments. Not all of these will be discussed here. In what follows we will mainly concentrate on what a new energy pricing policy means in terms of energy conservation and economic benefits, and what Iran's additional energy conservation potential is given the experiences of other countries. The reader should realize that this can only be implemented when Iran pays attention to the third strategy also. Currently the NIOC and the Iranian government are already working on this strategy.

4.7 Conclusions

Through SWOT analysis, three major strategies for Iran's domestic energy sector were identified. These are the achievement of energy conservation (with improvement of Iran's energy pricing policy at its core); continuation of the natural gas for oil substitution strategy; and reorganizing the domestic energy sector, with improved government decision-making through downsizing and liberalization of government owned enterprises at its core. How to support these measures remains to be discussed. This will be addressed in the following chapters. Chapter 5 discusses what type of model best suits our analyses. In Chapter 6, an econometric energy demand model and a no-policy-change (business as usual) scenario are developed. The trend in the demand per energy carrier shall be forecasted. In Chapter 7, the pricing and non-pricing energy conservation strategies will be quantified.

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Chapter 5
Energy Demand Modeling

5.1 Introduction

In this chapter a tool to quantify part of the strategies formulated in Chapter 4 is developed. Since the gas for oil substitution policy is already underway, special emphasis will be on developing a tool to quantify the energy conservation policy, with the domestic energy pricing policy as its backbone. Of course not all aspects of such a policy can be modeled explicitly. For example, the political problems related to a major revision of the domestic energy policy are not part of the model and will only be addressed marginally in this study. Also the restructuring of the government sector in general and the Ministry of Energy, and the Ministry of Petroleum and its main subsidiary the National Iranian Oil Company (NIOC) is not modeled explicitly.

There are many ways to model energy in an economy; see Girod (1991), Grubb et al. (1993), Hourcade et al. (1996), Kleinpeter (1995), and Beeck (1999). Choosing the correct model to evaluate strategies is a difficult task. What is required is a good balance between detail and goal; that is, choosing the system borders right and minimizing the possibility that variables that are outside these borders strongly affect the results.

The main goal of this research is to evaluate the opportunities of energy conservation in Iran, especially through an adjusted energy pricing policy, and the effect of continued gas for oil substitution. For this a model of Iran's domestic energy sector is required, that allows the evaluation of these strategies. Because the reduction in oil export capacity is a major problem, the effect of the domestic energy policy on oil exports and gross domestic product should be part of the analysis. These indicate the success of a strategy.

However, what is required first is a discussion on what types of models are available for the type of analysis we want to perform, and choose one. The most well known distinction in energy modeling is that of top-down and bottom-up, where top-down models analyze aggregate behavior, whereas bottom-up models rely on detailed description of technologies (Hourcade et al., 1996).

Another well-known distinction is that of general equilibrium as opposed to vector autoregressive models, with traditional structural economic or simultaneous equation models somewhere in between. These three general types of models are discussed and based on the pros and cons of each approach with respect to the goal of this research, the most appropriate model type is chosen.

Furthermore, models require data and data are often lacking in Iran. What is available for Iran and how these data were obtained is discussed separately.

The model should allow for the evaluation of changes in domestic energy policy, and the comparison of different scenarios over a time period of twenty to twenty-five years. The model is, however, not a tool to get precise forecasts of energy use development over the next twenty years. It should adequately cover the structure of Iran's domestic energy sector and indicate the effects of changes in Iran's domestic energy policy.

This chapter is organized as follows. Section 5.2 discusses criteria to guide the selection of an adequate model type and model specification. In Section 5.3 three different types of models, vector autoregressive, general equilibrium, and simultaneous equation, are briefly discussed, as well as the type of analysis they can be used for. Based on this discussion a type of model is chosen for our analysis. Section 5.4 reviews the data available for Iran. Section 5.5 combines the results of sections 5.3 and 5.4 to outline a model deemed most adequate for our analysis, taken into account the data restrictions. Section 5.6 draws conclusions.

5.2 Criteria for model selection

In Section 4.4 the strategic issues were grouped into *energy conservation*, which included energy intensity, technology improvement, energy pricing and subsidies, non-price energy policies; *the continuation of gas for oil substitution policy*, which is based on Iran's gas reserve abundance and its decreasing oil production capacity; and *improving the functioning of the government*, and more specifically Iran's energy sector is organized, was identified as a third strategic issue.

What can we infer from these issues for our model? First and most importantly, the model should allow the evaluation of changes in energy prices and how this affects the real gross domestic product, domestic energy use, and export revenue. So the model should clearly show the link between the real gross domestic product, domestic energy use, and export revenue. Therefore, the real gross domestic product should be endogenous.

The question is should the model cover factor income, that is, should the model cover economic activities as labor supply and demand? Since we are interested in the domestic energy sector and how it affects export revenue, this is not strictly necessary. Of course, a complete macroeconomic analysis allows the identification of who is going to gain and who is going to lose. However, for our purposes it is sufficient to identify the contribution of the policy to export revenue, which is dominated by oil revenue. Given the central role of the government in Iran's economy in general and the complete control over the energy sector in particular, it is up to the government how the extra oil revenue is used and there are many ways to let the Iranian people benefit. As we shall show in Section 5.4, there is one other good reason not to include factor income, and that is a lack of reliable data. For our purposes, a model that includes the main effects of domestic energy demand and oil export revenue, is sufficient. Since Iran is a developing country, it is assumed that an increase in the real gross domestic product is a sufficient indicator for improvement of the overall economy.

Domestic energy use can be divided into final energy demand and primary energy demand by the energy transformation sectors (electricity and refineries). The model should reflect this distinction if we want to analyze the potential contribution to energy conservation by Iran's inefficient transformation sector as well as that of the final demand sector.

Furthermore, the model should distinguish the demand per energy carrier in order to analyze the domestic energy sector in sufficient detail. Without knowledge on the demand for each petroleum product it is impossible to estimate the domestic demand for oil.

One of the strategic issues was technology improvement, since Iran's technology base is weak and obsolete. However, modeling technologies explicitly is difficult. The most well known approach is the MARKAL model, which has been (and still is) developed in a cooperative multinational project the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency. (See http://www.ecn.nl/unit_bs/etsap/main.html.) In the MARKAL model individual technologies are evaluated as well as their future development. Forecasting development paths of individual technologies for the next twenty years requires the expertise of many different experts, and is typically done by large research institutes, such as the International Institute of Applied System Analysis (IIASA) and the Dutch energy research institute ECN. (For an example, see Gielen 1997.) Furthermore, a detailed description of technologies used in Iran is not available, and as we will show below is also not required for the type of analysis we want to perform. Since virtually no energy efficiency improvements programs have been implemented in Iran so far, the potential for energy utilization improvement, on top of the energy pricing policy, can be estimated using experiences from other countries. Only when energy saving and technology improvement policies will be developed in the future, a detailed analysis of Iran's technology base is required. Finally, models based on detailed descriptions of technologies tend to be too optimistic with respect to energy conservation (Hourcade et al., 1996).

The model should confront domestic energy consumption and oil production, although a detailed analysis of actual oil production is not required. There certainly is a lot of room for improvement in this respect, but a detailed analysis of all producing fields, as well as all new reserves, is beyond the scope of this research. Iran's production potential is, however, an important input for the model. Without this, oil export cannot be determined. Furthermore, Iran has difficulties filling its OPEC quota, since its production capacity is gradually decreasing. Given the fact that Iran is in great need of foreign currency, we assume that Iran will always produce according to its production capacity.

Finally, the model should reflect the current situation in Iran, since this is the starting point of the analysis. The most important point is that the Iranian government sets energy prices, so these are policy variables and not the result of market forces; also see Chapter 2. Although the Iranian government is considering forms of deregulation and privatization in the energy sector, free markets for energy products, and as a result market prices, are not part of this policy. For this research we assume that the domestic energy prices remain administered prices. As was shown in Chapter 2, the current pricing policy results in very large implicit subsidies.

From this discussion we can deduct that the model:

- Should link domestic energy demand to GDP and export revenue,
- Does not require detailed descriptions of energy technologies,
- Should cover final and primary energy demand,
- Should distinguish between the different energy carriers,
- Include a representation of oil production in order to obtain oil available for export, and last but not least,
- Energy prices remain administered prices. Depending on the price path chosen implicit subsidies remain high or vanish.

Before we outline a model, we discuss three popular approaches to modeling, to see to what extend they meet our requirements for policy analysis.

5.3 Types of Models and Their Use

In this section we review three major types of models and discuss to what extend they fit our purposes as discussed in the previous section. A large number of energy models, many of which are special purpose models, have been developed; see Kleinpeter (1995), and Bunn and Larsen (1997). However, most modeling approaches analyze energy use in various sectors of the economy of non-energy producing countries. Another problem is that, especially when individual energy carriers are distinguished, it requires a level of detail that is at odds with macroeconomic analysis. What is required is a detailed analysis of energy carriers in combination with macroeconomic analysis.

Looking at the family tree of comprehensive economic models this can be thought of as varying from (applied) general equilibrium models (or (A)GE) via traditional structural economic or simultaneous equation (SE) models to vector autoregressive (VAR) models. In this range, AGE models have the most economic theoretical depth, but have a very liberal view on statistical methodology. VAR models on the other hand are very precise on the statistical level. Their economic content on the other hand is very low. Macro-econometric models have economic structure, but less stringent than AGE models. They do, however, apply statistical estimation methods to support equations, although data for sufficient statistical rigor are often lacking.

Next, these three types of models are discussed as well as their pros and cons for this study.

5.3.1 Traditional Econometric Models

Econometric models have been popular for a long time and were widely used in the Keynesian tradition. Despite many criticisms they are still widely used in applied work. The most well known macro-econometric model is most likely the Klein-Goldberger model (for a discussion, see Theil, 1971, pp 468-483), and the approach used was based on previous work by Tinbergen and Haavelmo. This type of model is called structural economic models or structural equation systems (the term structural was introduced by the Cowles Commission), because they are based on specific models of consumer, producer, etc. behavior. Others, with the statistical aspects of the models in mind, prefer to talk about simultaneous equation models (Jacobs and Wallis, 2002). We prefer this latter interpretation, since it better covers the approach, which not necessarily requires rigorous economic modeling. Many of the SE models used for policy support were (and are) often a mixture of theory and ad-hoc explanations, that is, partly based on economic theory and partly more descriptive with some economic common sense as a foundation for the equations in the model.

With the growth of computer capacity macro-econometric models for policy analysis became very popular, but due to data problems the statistical support was often flawed. Systems with thousands of equations were developed to support policy analysis. An example is the HERMES-model developed by the European Commission (Italianer, 1986). At the same time the economic foundation of this type of model was often incomplete. Many of the models used, were/are, despite their size, partial models and can be qualified as ad-hoc or descriptive models that, from an economic theoretical and a statistical point of view, are incomplete.

The general form of a linear SE model -which is the most widely used one- is

$$A(L)Y_t = B(L)X_t + \varepsilon_t \tag{5.1}$$

with $Y_t \in R^n$ the vector of endogenous variables, $X_t \in R^m$ a vector of exogenous variables, and $\varepsilon_t \in R^n$ a vector of random disturbances with $E\{\varepsilon_t\} = 0$ and $V\{\varepsilon_t\} = \Sigma_\varepsilon$. $A(L)$ and $B(L)$ are matrix polynomials in the lag operator L ($LX_t = X_t$), and $A(0)$ is normalized such that the diagonal elements are all equal to 1 and the matrix has full rank.

We can rewrite (5.1) as

$$Y_t = A(L)^{-1} B(L) X_t + A(L)^{-1} \varepsilon_t, \tag{5.2}$$

which is called the final form. The coefficients in $A(L)^{-1} B(L)$ are called the dynamic multipliers or impulse responses. When cumulated the long run multiplier effects are obtained.

Note that the disturbance term is interpreted as being the result of neglected variables (Theil, 1971, p. 104). If the model is formulated in line with economic theory these effects will be small and random, hence they can be neglected. This is in contrast to VAR models that have a different view on the role of the disturbance term in economic modeling; see Section 5.2.3.

The most fundamental economic theoretical criticism on structural economic models is the Lucas critique, which states that any change in the rules of economic policy will have an impact on the behavior of economic agents (Lucas, 1976). Therefore behavioral equations obtained by standard econometric methods will never adequately predict the result of policy changes.

In terms of model (5.1) the Lucas critique means that part of the parameters in the SE model, for example those of the private sector, are not independent of those of the other sectors, say the government. As a result these parameters might change in case of new government policies.

Although the Lucas critique points at a serious theoretical flaw in many economic empirical models, the quantitative effect of this omission might not be that serious. For example, VanBergeijk and Berk (2001) show that the policy advice based on econometric analyses of key financial economic relations remained valid for many European countries despite a major institutional change, the introduction of the Euro.

The Lucas critique has led to changes in the way economic problems are modeled. Two main directions can be distinguished. First, general equilibrium models that try to take into account all economic behavior in an economic theoretically correct way. Contrary to SE models, general equilibrium models incorporate optimizing behavior of economic agents an their expectations in a consistent way, and identify the basic (or deep) parameters of taste and technology. Second, vector autoregressive models that are based on reduced form equations and as such do not suffer from mis-specified economic behavior, because they don't require any behavioral theory. We will briefly discuss these two types of models, and then discuss the pros and cons of all three types of models.

5.3.2 General Equilibrium Models

Applied General Equilibrium or AGE models are based on the rigorous theoretical economic concept of a multi-market equilibrium, where all markets clear due to price adjustments. The central idea underlying this work is to convert the Walrasian general equilibrium structure (formalized in the 1950s by Kenneth Arrow, Gerard Debreu, and others) from an abstract representation of an economy into a representative model of the actual economy. Empirically based GE models, better known as computable or applied general equilibrium models, have been developed to evaluate concrete policy options. Shoven and Whalley (1992) describe all aspects of developing applied general equilibrium models, including developing an appropriate equilibrium structure, calibrating the model, compiling counterfactual equilibriums, and interpreting results. They state that the Walrasian general equilibrium model provides an ideal framework for appraising the effects of policy changes on resource allocation, for assessing who gains and who loses, and that these policy impacts are not well covered by traditional SE models.

Note that the econometric estimation of equations has in most AGE models been replaced by calibration of the model. The typical structure of an AGE model is one of nested functions of the Leontief, CD, CES, and CRESH type; see for example Adams et al. (1994) and Naqvi (1998). The coefficients used are not based on estimation, but (at best) on setting the parameters to meet the data in one or a few years. The coefficients are determined through what is called calibration, not estimation.

The functional forms used in many AGE models have been seriously criticized by McKintrick (1998). Although correct from an economic theoretical point of view, the functional (and numerical) structure used in AGE models strongly affects the results of policy simulations for small as well as large shocks. Based on a comparison between a CES based AGE and the normalized quadratic functional form, McKintrick concludes that better and more flexible functional forms for policy analysis in AGE models need to be investigated. Fox and Fullerton (1991) argue that the level of detail in AGE models should be considered carefully and show that similar results can be obtained with less detail.

The AGE-methodology allows the analysis of the impact of changes in the level of macro policy variables on protection, or the impacts of tax changes on different part of the economy. For example, an AGE-model could be developed to evaluate the effects of Iran's protection policy of non-oil import and its promotion policy of non-oil export; see for an attempt World Bank (2001). This calls for calculating the price indices for exportable, importable, and non-tradable goods. A drawback of AGE models is that they are not dynamic. They allow for a static comparative analysis only.

For dynamic general equilibrium modeling (DGE) a second type of general equilibrium model has been developed. A DGE is based on a concise mathematical formulation of the long-term behavior of all agents, and fully accounts for the effects of policy changes on model parameters. However, this type of model is not based on a complete description of the economy, but computes the equilibriums of fully specified but small artificial economies (Cooley and Dwyer, 1998). Many still see DGE models as too stylized and too remote from fitting the data for actual policy analysis (Sims, 1995)

Furthermore, DGE models are also often calibrated instead of estimated, and therefore are not based on a sound, complete and probabilistic assessment of model and data (Diebold, 1997).

5.3.3 Vector Autoregressive Models

Where general equilibrium models try to cover all economic theoretical criticisms of SE models, vector autoregressive or VAR models originally ignored all economic theoretical aspects. Sims (1980) criticized traditional structural economic (and rational expectations) models because they rely on unrealistic identification restrictions. Traditional SE models are often developed in parts. The restrictions introduced per part seem reasonable, but they become less reasonable when considering the complete system of equations. Furthermore, the assumptions on what is exogenous and what is endogenous are not based on economic theory.

Sims proposes to estimate models of the form

$$C(L)Y_t = \mu_t \tag{5.3}$$

with $C(L)$ a matrix polynomial with the identity matrix as the leading matrix, so the system is a reduced form system, and the elements of μ_t are correlated, so the variance matrix $E\{\mu_t\mu_t^T\} = \Sigma_\mu$ is not a diagonal matrix. (5.3) can be presented as a vector moving average model

$$Y_t = C(L)^{-1}\mu_t, \tag{5.4}$$

which can be used to calculate the impulse responses.

A clear distinction between VAR models and SE models is the absence of exogenous variables. A VAR model is a closed system in which all variables are endogenous. This approach meets with an important objection made by Sims, that the distinction between endogenous and exogenous in economic modeling is rather arbitrary. System (5.4) can be transformed via the Choleski decomposition of the variance matrix of the μ_t; that is, $T\mu_t = \varepsilon_t$ such that $E\{\varepsilon_t\varepsilon_t^T\} = T\Sigma_\mu T^T = \Sigma_\varepsilon$, into a recursive system

$$TY_t = TC(L)^{-1}\mu_t = \varepsilon_t + C^*(L)\varepsilon_{t-1}. \tag{5.5}$$

ε_t is white noise and the covariance matrix $E\{\varepsilon_t\varepsilon_t^T\} = \Sigma_\varepsilon$ is diagonal; T is the lower triangular matrix with ones on the diagonal from the Choleski decomposition.

An important difference between the SE approach and the VAR approach is the interpretation of the error process. Where in the SE approach these are interpreted as errors in equations due to the neglect of non-essential variables with minor influences, in VAR models the error terms are called structural innovations and are driving the stochastic dynamics of the equations (Gottschalk, 2001). In the VAR literature it is quite normal to name the individual error terms when analyzing the dynamics of the model.

A problem many researchers have with the VAR approach is its a-theoretical character and as a result that the impulse response analysis has no economic interpretation. Furthermore, the Choleski decomposition is not unique and leads to an arbitrary ordering of the variables, not an economic one, and the results so obtained can be sensitive to the ordering (Gottschalk, 2001).

This has lead to the development of the structural VAR or SVAR approach. Instead of using a-theoretical restrictions only, some of these are substituted by a-priori restrictions on the variance matrix of the orthogonal errors and/or restrictions on the impulse response based on economic theory. An example of the latter can be found in Blanchard and Quah (1989) where a monetary shock, interpreted as a demand disturbance, has no long-term effect on output or employment; also see Cooley and Dwyer (1998).

The popularity of the SVAR approach is increasing, because it allows an economic dynamic analysis rather than a dynamic analysis sec as the VAR approach does. For our analysis the SVAR approach rather than the VAR would be the one to use if this type of model were to be selected, since we are interested in economic policy rather than dynamics.

5.3.4 Pros and Cons

Each of the three model types in the previous three sub-sections has its strong and weak points.

The SVAR model, especially when the number of endogenous variables is large, requires a large number of covariance and/or economic restrictions to identify the model. In case of n variables, n(n-1)/2 identifying covariance restrictions are required (Garratt et al., 2000). These restrictions are difficult to obtain and it is unclear how they are related to an adequate economic theory. Furthermore, introducing these identifying restrictions was exactly what the original VAR approach wanted to avoid.

Cooley and Dwyer (1998) analyzed the exact nature of the identifying restrictions in an SVAR approach and compared these with those of a completely specified economic model. They argue that the SVAR approach uses a mixture of theoretical and a-theoretical restrictions. The, from an economic point of view, a-theoretical assumptions are concerned with the type of (non-)stationarity of the data, which can be tested, although these tests lack power. These assumptions are, however, crucial in an SVAR approach (Cooley and Dwyer, 1998). The a-theoretical assumption that the structural shocks are orthogonal is of crucial importance also, and this restriction cannot be tested, although it strongly affects the systems dynamics. The economic theoretical restrictions refer to economic theory, without formulating this theory explicitly, as DGE models do. Cooley and Dwyer conclude that the SVAR approach can easily lead to misinterpretations of what the important shocks are.

The number of variables in a macroeconomic SVAR model based on annual data is normally rather small due to data limitations. For this analysis, however, a larger model is needed, since we already distinguish eight types of fuels. Furthermore, a number of truly exogenous policy variables can be identified, the domestic energy carrier prices. Our analysis in Chapter 3 showed that these prices are set by the government and till now have hardly been affected by the development of Iran's economy; political gain seems to be a better guide. So there is no reason not to consider energy prices as exogenous variables.

The static AGE approach seems inappropriate for our purpose for the simple reason that the domestic energy market is not cleared through price adjustments. Of course one could argue that with prices set by the government, there will be market clearance through quantity adjustment. This is, however, not the case, because the energy carriers are produced in government owned facilities, and in several years and for several energy carriers the amount produced was not or hardly enough to meet demand.

The DGE approach seems promising, but for our purpose not suitable, since it is still in its development phase and only applied to artificial and small economies.

This leaves us with the simultaneous equation or SE modeling approach. Although this approach has its disadvantages, it seems the only approach that is robust enough to analyze Iran's domestic energy situation. We should, however, keep in mind the many problems that are inherent to this approach when analyzing the results.

Finally, in the literature there seems to be some convergence between VAR, SVAR, and SE modeling. Clements and Mizon (1991) suggest an approach that starts with VAR to search for the adequate dynamic structure, which is then used as a basis to search for an adequate SE model.

5.4 Available data

Consistent qualified data with the same frequency -needed for analysis and modeling-, are lacking in Iran. For example, the Central Bank of Iran (CBI) reports the main macro economic variables in the national accounts statistics, but also the Management and Planning Organization (MPO) (previously named the Planning and Budget Organization (PBO)) produces these data. However, the data from these two sources are not the same, which leads to ambiguity and inconsistency.

The same holds true for energy data. These are provided by different energy related ministries; for the structure of the energy sector see Section 3.5.1. And even within one ministry, one can find different values for the same variable. Furthermore, some data are classified as confidential by the Ministry of Petroleum and cannot be accessed by the public. When modeling Iran's energy sector this is a problem when building a consistent and disaggregated database.

Next, we discuss the data available and how we used the data to build a consistent database for our research. In Subsection 5.4.1 the available macroeconomic data are discussed. Subsection 5.4.2 reviews the energy data.

5.4.1 Macroeconomic data

Data on macroeconomic variables of the System of National Accounts (SNA) are collected and processed by the Central Bank of Iran (CBI), and the Management and Planning Organization (MPO). The MPO does this through its affiliation with the Iranian Statistic Center (ISC). The macroeconomic data produced by both, the CBI and the MPO, are not the same and in some cases, they are strongly inconsistent.

To be sure the macroeconomic data used are consistent, we tried to avoid using data from different sources. Here we use the data of the CBI, unless mentioned otherwise, since the CBI data are updated each quarter and each year, and are the most recent data available.

A problem that has to be resolved is the fact that the base year for macroeconomic data is updated every ten years. Therefore, one has to approximate the data when the base year changes. Fortunately, macroeconomic data in 1982 prices have been made available for the period 1974-1998. We will use these for our analysis and model estimation.

Although the databank on macroeconomic variables is relatively complete, there are still many problems when one tries to use these data. For instance, definitions have changed and new categories were added to the data set. An example is government income in Rial. The main categories were oil, tax, and other incomes, and the share of oil income was the highest in the portfolio. But recently a new category was introduced, called income initiated from "dollar sales". Actually, this category is oil income also, but now accounted for differently. "Dollar sales" is the value in Rial of dollars sold by the government on the free market (which officially did not exist for many years). These sales were recently added to the government budget as a new category, while these should be accounted for "oil income", as was the case in past before the government sold dollars at the free market.

Also, data on several important macroeconomic variables are lacking, making it impossible to construct a model for several parts of the economy. For example, including the labor market in the model is almost impossible due to lacking data. The numbers of employees for government and private sectors are available for the years of census (1966, 1976, 1986, 1991, 1996) while for the years in between the data are interpolated. The data on wages in the private and the government sector for different categories of employees are not available. The employment and unemployment rates in Iran are approximations also, since there is not an online system of registering the number of employees (full time or part time) in the private and the government sector.

Although capital formation is reported in nominal and real prices, these data are highly unreliable.

Constructing a model for financial and money markets has some data problems too. Lack of information on interest rates in the banking system and in the free markets is an example. Although recently (since 1995) all interest rates (reported as service commission) except for the free market are reported by CBI.

Different formal exchange rates during one financial year and in the course of time within the government allocation system and in the free market (which is not reported by CBI) is an obstacle for the formulation of a model of the trade sector.

5.4.2 Availability of Energy data

Data registration and collection differ for each energy carrier. Electricity and natural gas are registered at the end-user level through metering. These data are then gathered electronically; that is, registered manually on a regular basis and entered into a special recorder, which is then connected to a computer to read the recorded data. As a result, the final demand data for electricity and natural gas are fairly reliable and consistent.

Electricity consumption is the only energy carrier for which the data can be aggregated up to the generation level. These reliable and consistent data for electricity make it possible to draw up an electricity balance, which includes the final demand of all economic sectors: Residential and Commercial, Industry, Agriculture, and Others. By "Others" we mean wholesalers (mostly for very small villages), parks, mosques, etc. The net export of electricity to neighboring countries is reported as final demand also.

Natural gas is also registered at the end-user level, but not in the same detail as electricity. Although there are gas-metering systems in various sectors of the economy, the data published by National Iranian Gas Company (NIGC) is not based on these metering data. They report on the basis of larger metering systems, for example those at the entrance of distribution networks located in different parts of the cities. Therefore, data on natural gas demand in, for example the Residential and Commercial sector, are not exact data, but best guesses. The data for gas use in larger industries and in power generation are based on metered data. Because of the incomplete accounting, a gas balance for Iran is not provided.

The National Iranian Oil Refinery and Distribution Company (NIOR&DC) handles the distribution of petroleum products at the wholesale and the retail level. The major portion of gas oil and gasoline is sold by the private-owned gas stations, mostly to the gasoline and gas oil using cars. Farms buy their fuel from the gas stations too. The amount of gasoline and gas oil sold in the gas stations is ascribed to the transportation sector.

The gas oil for other sectors is distributed directly by NIOR&DC, which does not register the final users. Fuel oil is directly distributed by NIOR&DC also and the final user is registered. Jet fuel is used for aviation only. LPG is distributed in capsules, mainly to the Residential and Commercial sector. Bulk distribution of LPG to industry, large commercial firms, and the transportation sector is registered. Although fuel consumption in the various sectors is approximately registered, this is not reported.

Because of the differences in registration between fuels, all data regarding the consumption of petroleum products in different sectors of the economy as reported by the Ministry of Energy in the yearly energy balance are approximations. Therefore, reliable data on petroleum products consumption in different economic sectors are not available in Iran. This is especially true for the earlier years. Only for recent years the NIOR&DC reports the share of each petroleum product in the energy consumption of each economic sector. So, these data are available for a short period, but not enough to support econometric modeling.

The most reliable data for petroleum products are those of consumption per fuel, since they are registered when leaving the refineries or when imported or exported. These fuel consumptions are reported yearly by NIOR&DC and can be traced to the amount of crude oil feed to the refinery sector. Then using the amount of export, we can reach to the level of oil production. In other words, the balance on crude oil can be calculated.

The Ministry of Agriculture produces renewable energy in rural areas, and the Iran Atomic Energy Organization in other parts of the country. There is not a formal yearly report on the amount of renewable energy produced. Only recently the Ministry of Energy started to collect these data systematically and report them in the annual energy balance. The amounts are, however, rather small.

From the above we can conclude that consistent time series per fuel per economic sector are not available.

Although Iran is divided into 24 provinces by the Ministry of the Interior, this does not mean that all governmental entities will produce their data and information on the basis of this division. For example, the consumption of petroleum products are not available per province. But one can find data on specified geographical areas. These geographical areas (defined by NIOR&DC) do, however, differ from those of provinces. Therefore a good spatial model is not feasible either.

Energy balance

The Ministry of Energy processes the energy data and generates them in a yearly energy balance. Production of primary energies, import and export, demand of international bunkers, and domestic demand for primary energy are reported on the basis of barrel of oil equivalent or BOE values. Taking into account the changes in stocks and statistical discrepancies, the energy balance of primary energy is reported.

Losses that occur during the processing and own fuel use by the energy sectors are estimated and reported too. Therefore, by subtracting the losses and own use from the total primary energy demand, total final energy demand can be obtained.

The final energy demand for petroleum products, electricity, natural gas, and solid fuels is reported in BOE. Petroleum products are reported as a group, not as individual fuels, so separate data for jet fuel, LPG, gasoline, kerosene, gas oil, fuel oil are not provided in the yearly energy balance. As a result, one cannot use these data to construct a fuel model for the different petroleum products.

Remark: As was mentioned above, the data on economic sectors are only available for recent years. Therefore, when analyzing the structure of energy use in earlier years by economic sectors in Chapter 3, we had to use approximations based on the share information provided by the energy balance. We will, however, not use these approximations for our model.

As was mentioned in Chapter 3, border prices are used to calculate the implicit energy subsidies. However, these prices are not available for all fuels. For LPG only the prices for its components, i.e. butane and propane, are available. By applying the average share of these two as currently used to produce LPG we found that the price of LPG for the years for which we have data, was very close to the price of kerosene. Therefore, we use the price of kerosene as a proxy for the price of LPG.

The same price is used for jet fuels. The price of jet fuel in Iran is not available either. Since the price of jet fuel is very close to the price of kerosene in the international market, the price of kerosene was used as a proxy for the price of jet fuel also. Note that the demand for jet fuel is very small compared to the other fuels.

Energy data for modeling and forecasting

In order to construct a consistent and reliable database that can be used for econometric modeling, all energy time series have been collected on the basis of the units in which they are reported, and for each series the most reliable source was used. For petroleum products, including jet fuel, LPG, gasoline, kerosene, gas oil, and fuel oil, the formal reports of the NIOC and the NIOR&DC have been used. The data are reported by NIOR&DC in "Yearly performance of the NIOR&DC", in Farsi "Gozaresh Amalkard Salyaneh Sherkat Pakhsh". The data for the years before the formation of the NIOR&DC were obtained from the department of Corporate

Planning of the NIOC via direct correspondence. In case of inconsistencies, we discussed these with the persons responsible for the data. The total petroleum products consumption includes the consumption in final demand sectors and in power generation. In order to calculate the final petroleum product consumption from the total consumption one has to deduct the consumption in power plants. The petroleum products consumption in power generation was taken from "Detailed Electricity Industry Statistics", in Farsi "Amarhaye Tafsili Sanateh Bargh", published by the Ministry of Energy.

Total natural gas consumption is from the "Yearly report on natural gas", in Farsi, "Ghozaresh Salaneh Gas", published by the NIGC. The natural gas demand by the power sector is taken from "Detailed Electricity Statistics" published by the Ministry of Energy. Final demand for natural gas was obtained by subtracting the demand by the power sector from the total demand for natural gas.

The consumption of petroleum products in oil refineries is included in the crude oil feed. For natural gas consumption by refineries there is a technical relation, as will be explained in chapter 6. This relationship was calculated using the data reported in "Yearly performance of the NIOR&DC", issued by NIOR&DC.

The electricity data used are from "Detailed Electricity Industry Statistics", in Farsi "Amarhaye Tafsili Sanateh Bargh", and " 40 years electricity industry in Iran", in Farsi " Chehel Sal Sanat Bargheh Iran", published by the Ministry of Energy. The demand for solid fuels is from Iran's annual Energy Balance, published by the Ministry of Energy.

Using conversion factors, see Chapter 6, all energy data can be transferred to barrel of oil equivalent or BOE. The conversion factors used are those constructed by the Iranian Institute for Energy Studies (IIES). These may differ from those used by the Ministry of Energy and used to construct Iran's energy balance, but the factors of the IIES seem more reliable.

The prices of heavy and light Iran's crude oil on the international market are available, for our purpose we use the weighted average of heavy and light crude oil published by OPEC in Annual Statistical Bulletin (ASB).

Domestic energy prices are taken from different sources. The petroleum products and electricity prices are taken from the Energy Balance as published by the Ministry of Energy. Most recent prices were obtained through direct correspondence with the NIOC, the NIGC, and the Ministry of Energy. For the years of rationing of petroleum products (1987-1990 for gasoline and 1987-1989 for gas oil) the prices are the weighted average of the prices of the rationing system and the market prices set by the government. The weights are the shares of consumption in the two systems.

The price of natural gas was obtained via direct correspondence with the NIGC, Corporate Planning department.

5.5 General Outline of the Energy Model

This section contains a general outline of the SE model for our analysis and discusses the choices made. Based on the general outline of an energy system, types of models that can be used to derive an SE model are discussed. Based on data availability and the goal of this research, an adequate structure is formulated. In Sub-section 5.5.1 the main theories -not yet rejected above- used in energy modeling, are discussed. In Sub-section 5.5.2 an outline for the empirical analysis of Chapter 6 is formulated.

5.5.1 Review of Energy Models

Individual researchers, national organizations, and international organizations, such as the Iranian Institute for Energy Studies (IIES) and UNCTAD, have formulated several macroeconomic models of the Iranian Economy. Surprisingly, none of these models includes the domestic energy sector. This is mainly because domestic energy demand was, till recently, not considered an important issue. Implicitly it was assumed, as many Iranians still do, that Iran, as one of the leading oil exporters in the world, has sufficient resources to meet domestic demand and that this could never seriously affect export. As we have shown in Chapter 2, this assumption is false. As a result none of the models previously developed can be used as a starting point for our analysis.

For the formulation of the domestic use of energy, Figure 5.1 can be used. This figure starts with the demand for energy by the various sectors of the economy. The level of detail of the analysis (2, 3 or 5 digit according to the international data classification) is up to the researcher. Each sector demands one or more of the nine fuels distinguished for final demand: six petroleum fuels (jet fuel, LPG, gasoline, kerosene, gas oil, and fuel oil), plus natural gas, electricity, and others. In Iran the latter category is small and consists mainly out of coal and charcoal.

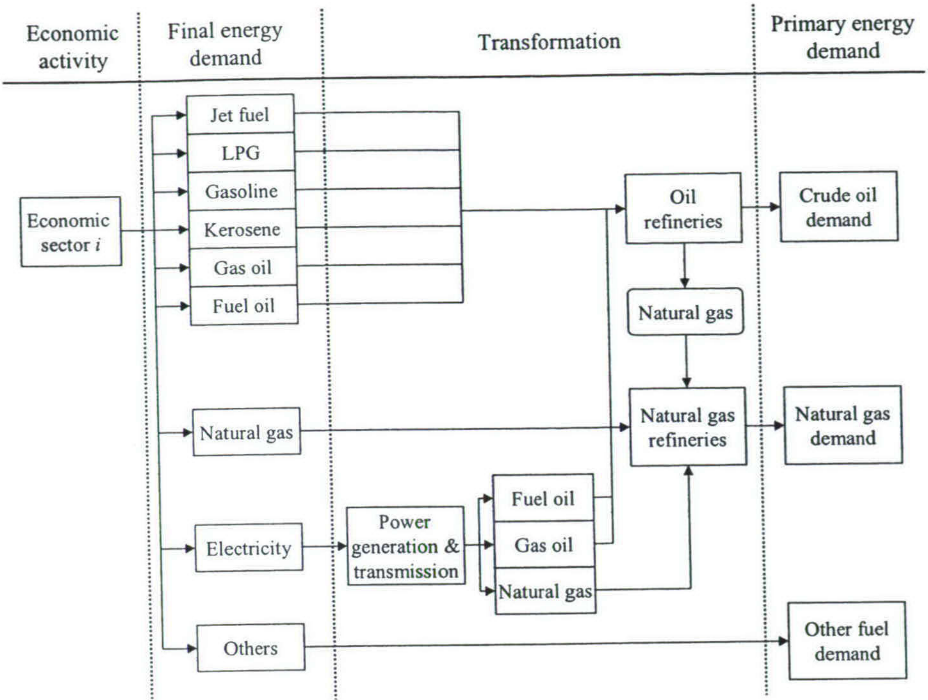

Figure 5-1. General outline of the domestic Iranian energy sector

Two transformation sectors, together covering the primary energy sector, are responsible for the production of the energy carriers demanded, the power sector and the refinery sector. In its thermal power plants Iran uses three fuels, gas oil, fuel oil, and natural gas. Iran also produces hydroelectricity, but for clarity reasons this is not depicted in Figure 5.1. In Chapter 6 hydroelectricity will, however, be modeled explicitly. Note that also own power production by factories and others is not included explicitly, but only through the demand for fuels.

The next question is how to model the final and primary energy demand. The first decision to make is whether the economic sectors or activities, or the fuel demand should be used as a starting point. The advantage of using economic sectors as a starting point is that a large number of approaches is available, some of which are discussed next.

Expenditure systems

To model final demand by the household sector a large number of demand models based on utility maximization subject to a budget constraint have been developed. This line of reasoning started with the Stone-Geary model based on a Cobb-Douglas utility function and a linear budget constraint. Since then many models have been developed, of which Theil's Rotterdam model (Theil, 1965), and Deaton and Muelbauer's Almost Ideal Demand System (AIDS) (Deaton and Muelbauer, 1980) are perhaps the most well-known. A wide variety of related models has been developed, see for example Neves (1994), and various forms have been tested (Tridimas, 2000).

For our purpose this approach has two disadvantages. First, energy is only a small fraction of consumer expenditure and small fractions tend to be poorly estimated. This would be especially true if, instead of using the general category energy, all fuels would be introduced. This disadvantage can be overcome somewhat by using an approach based on nested demand functions. Expenditure systems require, however, detailed data over a longer period. This brings us to the second disadvantage, the data to support such an approach for Iran are lacking.

Production and cost functions

For the manufacturing sector (or its sub-sectors) a large number of models have been developed too. Two important approaches are the production function approach and the cost/profit function approach.

Production functions are a powerful tool to model factor demand. Normally the production function is not used directly to derive factor demand, but factor demand is based on the assumption that producers (or in a macroeconomic context, a representative producer) minimize costs (or less widely used, maximize profit). Using Shephard's lemma share equations can be derived which can be estimated. For a comprehensive discussion of this approach we refer to Fuss and McFadden (1978). Since then many contributions and more flexible forms have been introduced. In applied work, the translog approach is the most popular one. For this research this approach would be a viable one, but as for household demand, Iran is lacking data, especially on capital stock and labor input.

Note that the mathematical formulation of production functions and their possibilities for a nested approach to demand is also popular in AGE models; for example see Naqvi (1998).

Descriptive models

Another approach that is popular in energy demand modeling is the use of energy intensity, which can be applied on the macro, sectoral or sub-sectoral level. For the development of future demand the adjustment of the intensities can be modeled as a function of energy prices and technology (Van Groenendaal, 1998). From an economic theoretical point of view this types of models can be regarded as ad-hoc models, since they are not based on optimizing behavior as the previous two approaches are. This approach requires, however, detailed information on the costs of various technologies, which is not available for Iran. This would require an energy audit of many production facilities, companies, and other users, which is beyond the scope of this research. This brings us to an approach that is feasible, fuel demand models.

Another type of descriptive models, which lack any economic theoretical content, and as such are really descriptive, use an index, to analyze different patterns in industrial energy demand (Unander et al, 1999; Luukkanen and Kaivo-ajo, 2002). This type of analysis is very useful to determine different effects in energy intensity, but for policy analysis it can only serve as an input not as analytical tool.

Fuel demand models

In a fuel demand model, the demand for a fuel is modeled as a function of the economic activity, its own real price and that of its main competitors, and other relevant explanatory variables. This approach can be applied for a single fuel as well as for several fuels (Belhaj, 2002; and Chow, 2001). The main difference between this approach and those based on explicit economic theory is that the explanatory variables are introduced on an ad-hoc basis, although they are similar to those in derived demand equations. Given the lack of detailed economic data for Iran this approach will be applied here too. The only reliable information available on energy use is total fuel demand for each of the nine categories mentioned above. The only refinement that can be made is based on the fact that data on total final energy demand; that is, energy demand by households and small commercial enterprises, agriculture, manufacturing, transport, etc., are available, as well as energy demand by the power and the refinery sectors.

5.5.2 A Simultaneous Equation Model for Iran's Domestic Energy Sector

In this subsection a model is formulated that shall serve as a starting point for the estimation in Chapter 6. The model contains four sub-models: the final demand per energy carrier, the primary energy demand that results from the final energy demand, a small Keynesian macroeconomic model to link the effects of the domestic energy use to the gross domestic product, with special emphasis on the effect of oil revenue on domestic expenditure, and finally equations to calculate the implicit subsidy on final energy demand.

Final energy demand

For each fuel the following general equation will be used as a starting point for the empirical model of Chapter 6:

$$Di_t = f(RPj_t, EA_t) + \varepsilon i_t. \tag{5.6}$$

Di denotes the demand for fuel *i*, *RPj* the real price of fuel *j*, *EA* the indicator for the relevant economic activity, and $i,j \in$ {jet fuel, LPG, gasoline, kerosene, gas oil, fuel oil, natural gas, electricity}. As was mentioned in Chapter 2, in Iran the government sets the prices of all energy carriers. In Chapter 6 Equation (5.6) will be made more precise and attention will be paid to the dynamic structure.

What is used to indicate economic activity will depend on the actual fuel. In some cases this will be real gross domestic product, but for others this can be pinpointed more precisely. For example for jet fuel the amount of cargo and the number of passenger kilometers are better explanatory variables. For the demand for gasoline the stock of cars seems a logical choice. Of course the model has then to be augmented to cover these additional variables.

Primary energy demand

The demand for fuels in the transformation sector will be based on the technical coefficients of the power and the refinery sector. Since energy prices for these sectors are not available (and seem to play hardly any role in the decision process), the demand for fuels in thermal power plants (gas oil, fuel, oil and natural gas; see Figure 5.1) will be based on the demand for electricity only.

$$Di_t = f(Delectricity_t) + \varepsilon i_t . \tag{5.7}$$

Di denotes the demand for fuel *i* by the power sector, *Delectricity* the demand for electricity, and $i \in \{\text{gas oil, fuel oil, natural gas}\}$.

The final demand for petroleum fuels in combination with the demand for gas oil and fuel oil by the power sector results in the total demand for petroleum products, which has to be met by the refinery sector. In the past the capacity of this sector was in most years sufficient to meet domestic demand, with the exception of gasoline, some of which has to be imported from neighboring countries. The gross demand for oil by the refinery sector is modeled by the technical coefficients of historical production efficiency.

The demand for natural gas needs extra attention, since Iran has already implemented a natural gas for petroleum products substitution policy. The model should adequately reflect the effects of this policy.

Since we require the real prices of energy carriers in Equation (5.6), the consumer price index (CPI) is modeled also. The analysis of Chapter 2 shows that this variable will depend on Iran's policy on liquidity creation over real economic growth (GDP), which according to the quantity theory of money is the main contributor to inflation. For our analysis it is assumed that liquidity is an exogenous variable.

Oil for Export

A result of the analyses of final and primary energy demand in combination with the technology coefficients of the transformation sector will, among others, be the demand for crude oil for domestic use. If this is subtracted from the amount of oil produced, the amount of oil available for export is obtained. Since oil prices are determined by global oil demand and supply, oil prices are exogenous for Iran. So with the export of oil and a reference path for oil prices, the value of oil export is determined. This revenue is by far the main component of Iran's dollar income, which in turn affects expenditure. This part of the model is depicted in Figure 5-2.

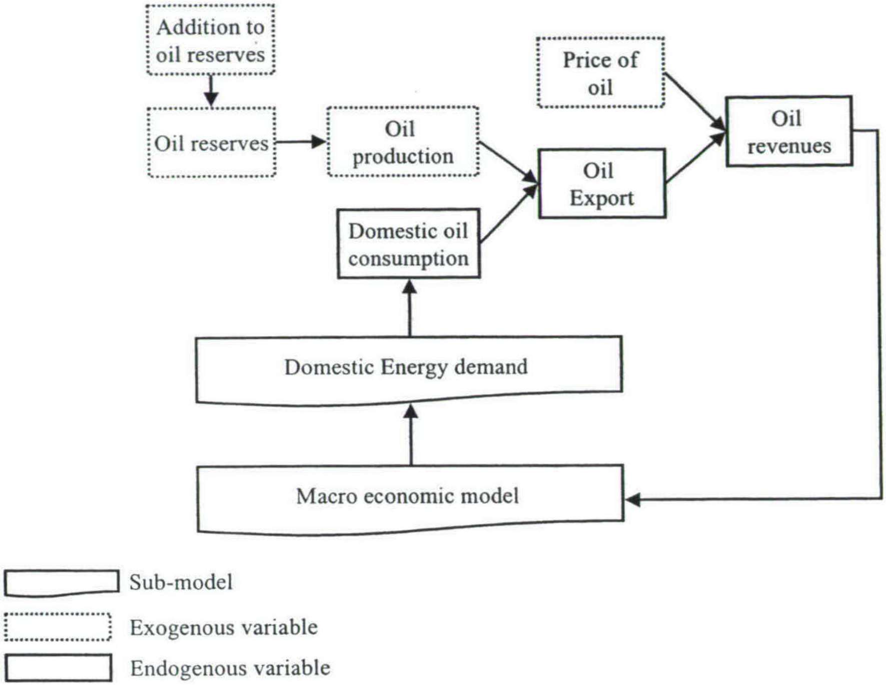

Figure 5-2. Oil production and export

Implicit Energy Subsidies

The border prices of all energy carriers are exogenous to our approach. Given the domestic prices of petroleum products, as well as natural gas and electricity, the implicit subsidies can be calculated.

To calculate the implicit subsidies we need either domestic energy prices in US$, or the border prices of the energy carriers in Rial. Either way, the free market exchange rate is required for this. Therefore, the free exchange rate is included in the model.

Economic Activity

The final part of our model is the link between real gross domestic product (GDP) and the effect total dollar inflow (R$) has on it. For this we model the main components of GDP, real private consumption (CP), real investments (I), real government expenditure (G), and real import (M). Note that the major part of export (X) is already determined above by oil export. Iran's non-oil export is relatively small (around 20%

of the total) and diverse, subject to much government regulation, and therefore not endogenous in the model.

Each demand category is assumed to be affected by real income, dollar inflow, and possibly other variables. The latter depend on the particular demand category. The general formulation of the equations is:

$$Cp_t = f(Income_t, R\$_t, Z_t) + \varepsilon_t \tag{5.8}$$

$$I_t = f(Income_t, R\$_t, Z_t) + \varepsilon_t \tag{5.9}$$

$$G_t = f(Income_t, R\$_t, Z_t) + \varepsilon_t \tag{5.10}$$

$$M_t = f(Income_t, R\$_t, Z_t) + \varepsilon_t \tag{5.11}$$

Z_t denotes the possible exogenous variables. The real effect of the dollar inflow depends of course on a much more complex politically motivated decision process. However, we assume that this effect can be adequately quantified in this way. The total real gross domestic product GDP is defined as:

$$GDP_t = CP_t + I_t + G_t + X_t - M_t \tag{5.12}$$

In Figure 5-3 all models are combined. A darker background indicates the boxes containing the most important variables. If we start reasoning from real gross domestic product, the figure shows that this will affect the final demand of energy carriers, as do their real prices. On one hand, this final energy demand allows us to calculate primary gross energy demand, and on the other, it allows us to calculate the amount of implicit subsidies on final energy demand. For the latter the border prices and the free market exchange rate are required.

The domestic demand for oil together with oil production results in another variable of major importance, oil export. If we multiply this by the price of oil, oil revenue is obtained. This in turn determines, together with non-oil export revenues and foreign direct investment, the total dollar inflow. This variable is again an important input for the demand categories that constitute gross domestic product, which shows the main feedback mechanism in the model.

Another important feedback is between GDP, as a measure of real income, and the main demand categories. We will return to this in Chapter 6.

The main exogenous variables are the price of oil, oil production, and liquidity. The other exogenous variables are of course important also, but are expected to have a less significant effect.

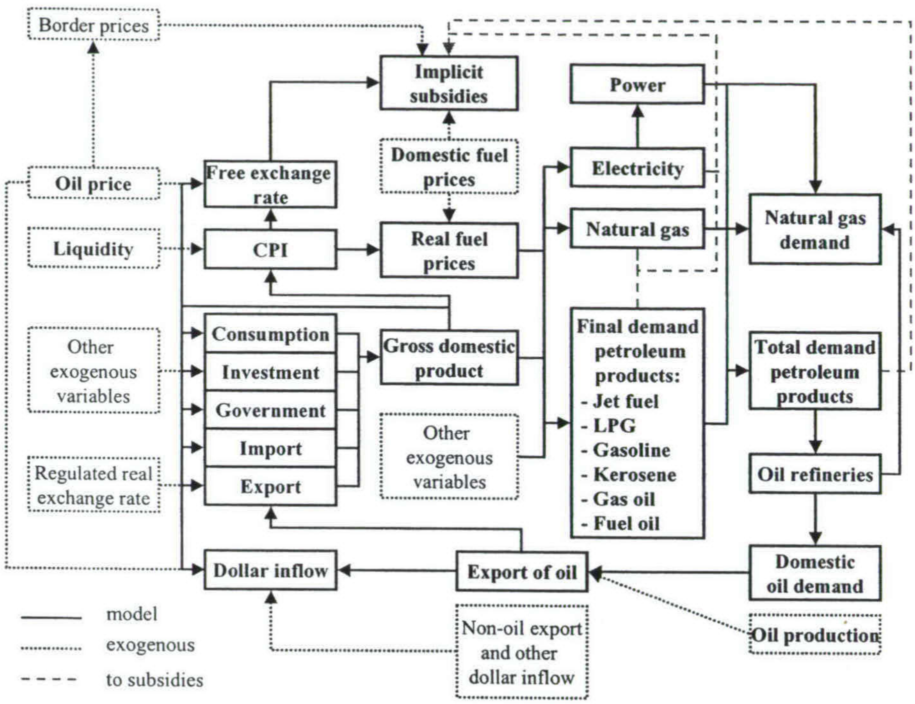

Figure 5-3. Main relationships in the overall model

Note that two exchange rates are distinguished, a regulated one and the free exchange rate. The regulated exchange rate is used solely to transfer export in US$ to real export in Rial, so it actually covers the exchange rate effect and the domestic price of exports. This is necessary to account for the many exchange rate regimes that were used by the Iranian government in the past; see Chapter 2. The free exchange rate is the market exchange rate, as it is known in non-regulated economies all over the world.

5.6 Conclusions

Before a model can be formulated, it is wise to investigate the boundaries of the problem. The main requirements for the model are that (i) it should link domestic energy demand to real GDP and export revenue, (ii) detailed descriptions of the energy technologies used in Iran are not required, (iii) the model should cover final and primary energy demand and distinguish the different energy carriers used in Iran. Furthermore, it is assumed that Iran's domestic energy prices remain administered prices, so these will not be modeled as market prices when introducing a new energy pricing policy. A model based on these constraints allows us to analyze Iran's domestic energy market and how it affects economic growth, which is one of the main goals of this research.

Next, the pros and cons of three important ways to formulate a model - simultaneous equation or SE models, general equilibrium or GE models, and vector autoregressive or VAR models-, were discussed. Each of these approaches has its merits, and each can be criticized. We concluded that the traditional SE approach suited our purpose best, despite its drawbacks.

Since sound data is a problem in any study, and especially in a developing economy -which Iran still is-, attention was paid to the data available for Iran. This analysis shows that many of the popular approaches used to model energy demand cannot be used to model Iran's domestic energy sector.

With the type of model and the data restrictions in mind we used an outline of Iran's domestic energy system as a starting point to formulate a model that is suitable for our purpose. Figure 5-3 contains a general outline of the model that will be made more precise and estimated in the next chapter. The model is only a partial model of the economy, with emphasis on domestic energy. We are, however, convinced that it is sufficiently well specified for our analysis.

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Chapter 6

Estimation, Simulation, and Forecast of Iran's Final and Primary Energy Demand

6.1 Introduction

The general outline of the model developed in Chapter 5 will be made concrete and estimated in this chapter. The goal of the model is to describe the interactions between Iran's energy sector (more in particular its domestic energy sector) and Iran's macro economy in sufficient detail for our long-term analysis of domestic energy policies. Indeed, the major variables that affect the demand for different energy carriers shall be obtained through analyzing the main energy consuming sectors for each energy carrier. Each equation specified in this way is then estimated in order to select the proper one using econometric criteria. Finally, this set of estimated equations is completed with identities to form a complete model that can be used for policy analysis and projection.

The objective of this research is to analyze the effect of possible energy policy rules that will increase the overall benefits of Iran's oil and gas production. For this it is necessary to forecast the level of domestic energy demand based on the current non-optimal situation of low energy prices and a large government sector, resulting in inefficient energy use (see Chapter 2 for details). The model developed in this chapter will be used to forecast domestic energy demand for each energy carrier in case of no change in policy. In Chapter 7 the model will be used to analyze the effect of removing the implicit energy subsidies reported in Chapter 2. The effect of this policy on the trend of energy demand and on energy efficiency of the whole economy is evaluated.

Because of the feedback mechanisms between the macro economy and the energy sector identified in Chapter 5, the overall model actually comprises four sub-models: (i) a small Keynesian macroeconomic model to simulate the main economic activities, (ii) a model for final energy demand, (iii) a model that translates total final energy demand into primary energy demand, and (iv) a model for implicit subsidies.

This chapter is organized as follows. Section 6.2 discusses the statistical procedure used to obtain the estimated equations. The estimation results are reported in Section 6.3. Subsection 6.3.1 discusses the macroeconomic model, Subsection 6.3.2 the final energy demand model, Subsection 6.3.3 deals with the energy transformation activities (power plants and refineries), and finally Subsection 6.3.4 discusses the subsidy model. Section 6.4 first covers the assumptions on the models exogenous variables up to 2020; next the business as usual or reference scenario is discussed. Section 6.5 contains conclusions.

6.2 Methodology Applied

The behavioral equations of the model are estimated using either two stage least squares, (Greene, 1993, pp. 603-605), denoted as 2SLS, or ordinary least squares, denoted as OLS (Greene, 1993, pp. 358-381). Each estimated equation is evaluated using:

- the goodness-of-fit measure R^2_{adj}, which indicates the portion of the variance explained by the model over the total variance in the endogenous variable, but is adjusted for the number of explanatory variables used. The adjustment is based on the philosophy of parsimoniousness in model building. Note that the value of R^2_{adj} is smaller than one, but can in extreme cases become smaller than zero.
- the Student t-statistic for individual coefficients is used to test the hypothesis that an individual coefficient is equal to zero. With K+1 the number of explanatory variables and N the number of data in the sample, the t-statistic is defined as $t_k = {\beta_k}/{S_{\beta_k}}$, which has a *t* distribution with $N - K - 1$ degrees of freedom; β_k is the estimated coefficient, and S_{β_k} its estimated standard error that can be obtained from the regression variance matrix.

- the F-statistic on joint significance of the estimated coefficients, that is, the test $H_0 : \beta_0 = \beta_1 = ... = \beta_k = 0$. This test is based on the residual some of squares of the restricted and the unrestricted model.
- the Durbin and Watson or DW-statistic on first order autocorrelation and the h-DW in case lagged endogenous variables are present in the model. The DW statistic ranges from zero to four, with a value near 2, indicating no first-order serial correlation.

  If the lagged endogenous variables are present in the equation, the DW statistic cannot be used. In this case it is substituted by the Durbin *h*-statistic, which is defined as $h - DW = \left(1 - \frac{DW}{2}\right)\sqrt{\frac{N}{1 - N[\text{var}(\beta)]}}$, with $\text{var}(\beta)$ the estimated variance of the coefficient of the lagged endogenous variable (Pindyck and Rubinfeld, 1998, p. 169). *h-DW* is approximately standard normally distributed, so the test can be done by using the quantiles of the standard normal distribution. The null hypothesis is "no serial correlation", and if rejected first-order serial correlation exists. In other words, if the estimated *h-DW* is larger than the critical value, the residuals are autocorrelated.
- the Augmented Dickey-Fuller-test (ADF) is applied for unit root diagnostic checking. In empirical econometric work, it is assumed that the time series used are each from a (covariance) stationary stochastic process, that is, a process with a finite constant mean and variance, and autocovariances that only depend on the distance in time between two observations (Verbeek, 2000, p. 229). If the time series data are non-stationary, the criteria to evaluate equations discussed above are corrupted and may result in what is known as spurious regression (Verbeek, 2000, p. 281). The relationship between the non-stationary variables can be based on the fact that they are both trended and this should not be mistaken for a causal relationship that may not exist. Therefore, it is tested if the residuals of each estimated equation are stationary using the (augmented) Dickey-Fuller test (ADF test) with an intercept and one lag. The null hypothesis is that the residuals are not from a stationary stochastic process as assumed; this is also known as the unit root hypothesis. In case this hypothesis is rejected, the equation is cointegrated. The MacKinnon critical values for the rejection of the unit root hypothesis as reported in the statistical package Eviews will be used; at the 1%, 5%, and 10% level and

for 23 observations these are -3.785, -3.011, -2.645 respectively. In the sequel we will indicate these three significance levels when we report on the ADF test by *, **, *** respectively.

Remark: For a SE model a more comprehensive test is actually required, but this testing is still in its infancy; see Hendry and Juselius (2001).

- Finally, for each equation a figure is included in which the actual and the simulated data are confronted. Note that the simulated data are based on the dynamic simulation of the complete SE-model over the sample period.

The estimated equations reported in Section 6.3 below are judged on the tests discussed above. The log-log autoregressive distributed lag model is used as a starting point for the estimation of each equation. One of the advantages of this approach is that the coefficients are elasticities. Only in a limited number of cases the log-log linear form had to be abandoned due to unsatisfactory results. For more detailed explanations of the theoretical foundation of the statistic and diagnostic tests used, as well as statistical tables to apply them, we refer to Greene (1993), Pindyck and Rubinfeld (1998), or Verbeek (2000).

Finally, the estimation period used covers three hectic periods in the history of Iran; the period before the Islamic revolution (1974-1979) in which the political situation was already unstable; the period 1979-1988, with the revolution in 1979 and in which Iraq invaded Iran, resulting in a seven year war; and the period 1989-1998 in which Iran is still in a politically difficult period, but which is a quiet period compared to the previous periods. Econometric modeling is difficult as it is, without data that account for such difficult times. We did not test whether different models are valid for these different periods. The data periods are too short for formal testing. However, every equation was re-estimated for other periods than 1974-1998, and the results were compared to those based on this time period. These results indicated that the estimated equations reported below are stable in the sense that the most of the explanatory variables remain significant and that the estimated coefficients do not change too much. The only exception is the equation for CPI, which is therefore based on a different estimation period (1979-1998).

6.3 Estimation Results

Each of the four sub-models mentioned above are developed in this section. In Sub-section 6.3.1 the Keynesian macroeconomic model is formulated, in Sub-section 6.3.2 the final energy demand model, in Sub-section 6.3.3 the primary energy demand model, and finally in Sub-section 6.3.4 the subsidy model.

Since we estimate behavioral equations of a SE model, each individual equation needs to be identified. It ca be shown that all equations in the simultaneous part of the model are over-identified and can be estimated by 2SLS or the instrumental variables or IV method. The recursive equations and other auxiliary equations can be estimated by OLS. For the estimation time series data for the period 1974-1998 are used.

6.3.1 The Keynesian model

The Keynesian macroeconomic model is very small and only contains equations for private consumption, investment, government expenditure, and net exports (i.e. export minus import); also see Chapter 5. All endogenous variables are in 1982 market prices. The individual equations of this model are discussed next.

Consumption expenditure

Consumption expenditure, further denoted as CP, is a function of real gross domestic expenditure (GDE), population (POP), and the level of Dollar inflow (R$). The estimation method used is 2SLS.

$$\begin{aligned} LOG(CP) = \; & \underset{(-4.36)}{-7.898} + \underset{(1.38)}{0.137}*LOG(GDE) + \underset{(4.70)}{0.663}*LOG(POP) \\ & + \underset{(2.67)}{0.152}*LOG(R\$) + \underset{(2.82)}{0.376}*LOG(CP(-1)) \end{aligned} \tag{6.1}$$

EM: 2SLS; $R^2_{adj} = 0.96$; DW = 1.55; h-DW = 1.43; ADF = -3.18**

All coefficients have the expected sign and all but one, GDE, are statistically significant. The critical value of two-tailed t test at the 95 percent and with 19 degrees of freedom is 2.093.

With R^2_{adj} equal to 0.96, the equation has a good fit.

Figure 6-1 shows that the values of the dynamic simulation of the complete SE model (denoted by CPRF) are in line with the actual values (denoted by CP).

Since the calculated h-DW is 1.43, which is lower than the 0.95 table value of 1.645, the null hypothesis of serial correlation is rejected.

The ADF statistics rejects the null hypothesis of being non-stationary at the 95% level. Since the residuals of the simulated equation are stationary, the estimated equation is cointegrated.

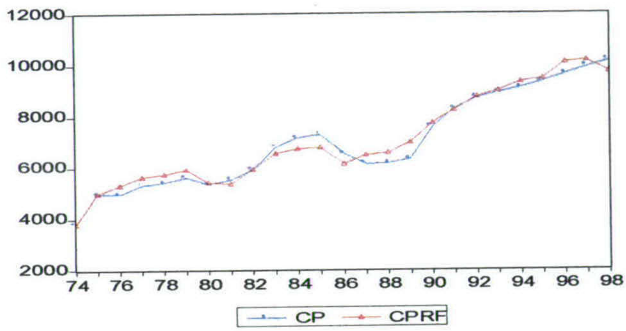

Figure 6-1: The actual and simulated values of CP in billion 1982 Rial

The short and long term elasticities for GDE, the income effect, are 0.137 and 0.220 respectively, which seems rather low. Iran's population growth has a larger effect on consumption expenditure, 0.663 in the short and 1.063 in the long run. For R$ these values are 0.152 and 0.244 respectively.

Investment Expenditure

Private investment (I) is a function the dollar inflow R$, the dollar value of capital goods import (CAPIM$). A higher level of dollar inflow enables a higher level of investment. The capital goods import indicates the government policy on lifting import restrictions. The following equation was obtained.

$$\begin{aligned} \text{LOG(I)} = \; & \underset{(0.53)}{0.492} + \underset{(2.22)}{0.281}\text{*LOG(R\$)} + \underset{(2.37)}{0.158}\text{*LOG(CAPIM\$)} + \\ & + \underset{(6.143)}{0.665}\text{*LOG(I(-1))} \end{aligned} \tag{6.2}$$

EM: 2SLS; $R^2_{adj} = 0.78$; DW = 1.28; h-DW = 2.00; ADF = -2.82***

All coefficients are statistically meaningful, except for the intercept, and the signs of the estimated coefficients are as expected. The adjusted R-squared of 0.78 indicates a proper goodness of fit, given the fact that investment equations are hard estimate. The h-DW statistic rejects the null hypothesis of first order serial correlation. The investment equation satisfies the cointegration test at the 90 percent level. Figure 6-2 shows the actual and simulated trend of investment, having slight differences in some years.

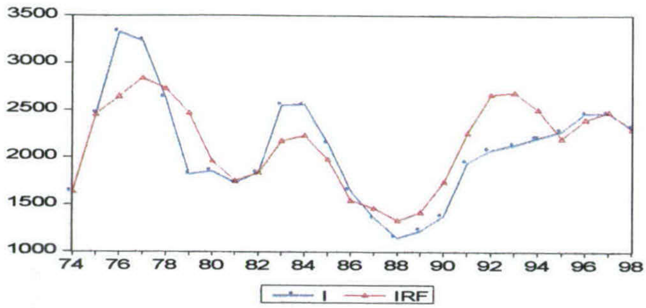

Figure 6-2. Actual and simulated values of I in billion 1982 Rial

In Iran the dollar inflow is an important determinant of investment expenditure, since one percent increase in its level leads to a 0.28 percent and 0.84 percent increase in the level of investment in the short and long term respectively. In addition, the restrictive import policy of investment and capital goods as well as the long term international embargo have affected the overall investment expenditure in Iran, since one percent increase in the level of capital goods import indicates 0.14% and 0.44% increase in the short and long run, respectively.

Government Expenditure

Iran's dollar income (R$) is mainly earned by and allocated to the government sector. So it is reasonable to assume that it affects real government expenditure (G). In recent years this effect has strengthened, because the government can, via selling part of its oil dollar income on the free exchange market, increase its income in Rials. On top of R$, also a higher level of GDP causes a higher level of tax-income for the government, encouraging in turn more government expenditure.

$$\text{LOG(G)} = -0.309 + 0.214^{*}\text{LOG(R\$)} + 0.150^{*}\text{LOG(GDE)} + \atop \quad (-0.40) \quad (3.53) \qquad\qquad (1.88)$$

$$+ 0.774^{*}\text{LOG(G(-1))} \atop (10.3) \qquad\qquad (6.3)$$

EM: 2SLS; $R^2_{adj} = 0.88$; DW = 2.13; h-DW = -0.40; ADF=-3.70**

All coefficients are statistically meaningful and their signs are as expected. The h-DW statistic indicates the null hypothesis of the first order serial correlation is rejected.

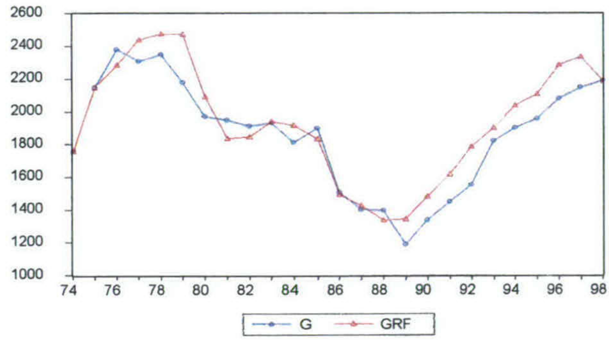

Figure 6-3. Actual and simulated values of government expenditure in billion 1982 Rial

A one percent increase in R$ causes a 0.21% increase in G in the short run and 0.93% in the long run. This clearly indicates the strong effect oil revenue has on government expenditure and given the fluctuating nature of this variable, its potential for destabilizing government policy. This effect is amplified by the effect R$ has on private consumption and investment. The effect of GDE is much smaller, 0.14% in the short term and 0.62% in the long term.

Export

Iranian export (X) consists of oil, and non-oil exports. The latter is, however, relatively small and is therefore not modeled separately, but treated as an exogenous variable. Note that this non-oil trade is also restricted by the boycott of many Iranian products by the USA.

The amount of oil exported is determined endogenously by subtracting domestic demand for oil from production. However, this is part of the energy model discussed below.

Because of the many restrictions on trade and the many exchange rates used in Iran during the estimation period (see §2.2.3), a separate variable called average exchange rate (AERC) is introduced to convert US$ into Rial.

The following equation describes export in 1982 prices (X) as a function of R$ net of the exogenously determined foreign direct investment (FDI).

$$X = AERC^*(R\$ - FDI) \tag{6.4}$$

This identity is the major link between the macroeconomic model and the energy block of the model. Next, we estimate an equation for AERC.

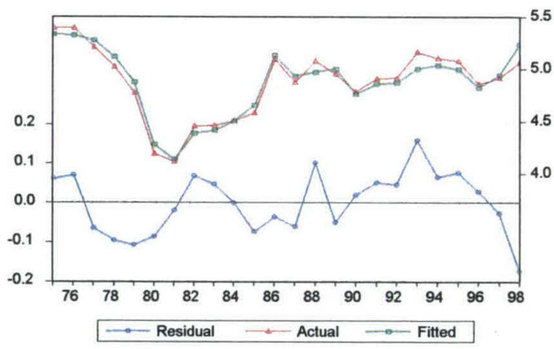

Figure 6-4. The actual and fitted values of AERC

Average conversion rate

The average rate to convert the dollar value of export into real Rial values (AERC) is affected mainly by the price of oil (POIL). Since the oil prices are exogenous in this model, the log-log functional form of the AERC can be estimated by OLS. It is expected that a lower AERC is associated with the higher oil price.

$$\underset{(12.1)}{LOG(AERC) = 6.244} - \underset{(-10.1)}{0.697}*LOG(POIL) + \underset{(1.8)}{0.133}*LOG(AERC(-1)) \tag{6.5}$$

EM: OLS; $R^2_{adj} = 0.94$; DW = 1.01; h-DW = 2.50; ADF = -2.04***

Each coefficient is statistically meaningful and the equation has a good fit. This is confirmed by Figure 6-4, which, together with the familiar simulated and actual data, also shows the residuals of the estimated equation in connection with the higher and lower bound of the standard deviation of the residuals. The ADF test rejects the unit root hypothesis of the residuals.

Imports

Imports (M) are modeled as a function of dollar inflow R$ and a time trend. The dollar inflow indicates Iran's ability to purchase foreign goods and services. As indicated in Chapter 2, Iran's import is strongly affected by government policy, which has lead to a continuous reduction in imports in real terms. This effect is covered by a time trend. The lagged import variables depict the adhesive structure of Iran's Import.

$$\begin{aligned} LOG(M) = {} & \underset{(3.2)}{4.067} + \underset{(1.2)}{0.205}*LOG(R\$) - \underset{(-2.62)}{0.022}*TREND + \underset{(4.1)}{0.847}*LOG(M(-1)) \\ & + \underset{(-2.48)}{0.461}*LOG(M(-2)) \end{aligned} \tag{6.6}$$

EM: 2SLS; $R^2_{adj} = 0.78$; DW = 2.17; ADF = -2.54**

All coefficients are statistically meaningful at the 95 percent level, except the dollar inflow (R$). Because Eq. (6.6) contains two lagged dependent variables, the h-DW test cannot be used. To test for autocorrelation the residual was modeled as $e_t = \alpha + \beta e_{t-1} + \varepsilon_t$, and since β was not significant the hypothesis of first order serial correlation can be rejected. The value of R^2_{adj} suggests an acceptable goodness of fit, which is supported by Figure 6-5. According to ADF the null hypothesis of unit roots can be rejected, so the equation is cointegrated. The import elasticity of dollar inflow shows that a one percent increase in the dollar inflow causes an immediate increase of 0.21% in imports in the short term and 0.34% after full adjustment.

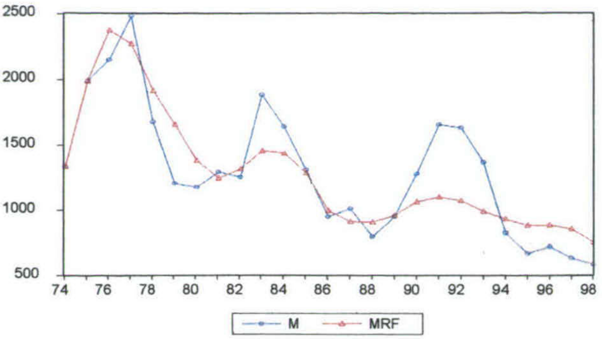

Figure 6-5. The actual and simulated values of M in billion 1982 Rial

Real Gross Domestic Expenditures

By definition real gross domestic expenditure is the sum of private consumption, investments, government expenditure and net export. The gross domestic expenditure at 1982 market prices (GDE) is

$$GDE = CP + I + G + (X - M) \tag{6.7}$$

Note that the equations (6.1) to (6.6) define GDE, while in turn CP and G are affected by GDE.

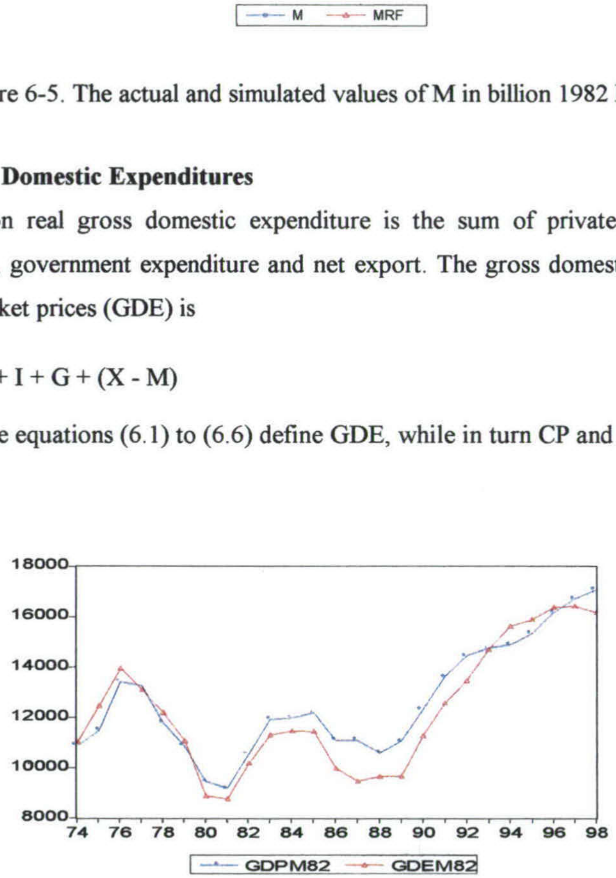

Figure 6-6. Real GDE and real GDP in billion 1982 Rial

Real Gross Domestic Product

Theoretically, real gross domestic expenditure (GDE) should be equal to real gross domestic product (GDP). In Iran there are, however, significant and persistent statistical differences between these two variables, although their general trends are the same; see Figure 6-6

In the energy demand equations, GDP is an important explanatory variable, whereas GDE plays an important role in the macroeconomic model. Therefore, we estimated an equation linking GDE and GDP. The following equation, estimated by 2SLS, produces a simple relationship between them.

$$GDP = 1826.33 + 0.807{*}GDE - 1019.6{*}DGDE + 81.54{*}TREND \qquad (6.8)$$
$$(4.8) \qquad (22.3) \qquad (-4.3) \qquad (6.5)$$

EM: 2SLS $\overline{R^2} = 0.98$ DW=1.99 ADF=-3.5**

In Eq. (6.8) DGDE is a dummy variable that is one for the years of 1994, 1995, and 1996, and zero elsewhere. This dummy is needed because the value of GDP has been greater than that of GDE except for these three years.

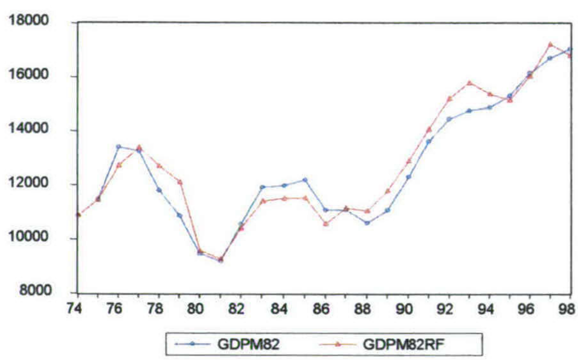

Figure 6-7. The actual and simulated values of real GDP in billion 1982 Rial

Dollar Inflow

The total level of dollar inflow is the sum of oil and non-oil export revenues, and foreign direct investment. Since about six years there is one extra item that needs to be considered, dollar expenditures due to buyback contracts. In a buyback contract Iran uses foreign investors to develop an oil field and the principal investment plus interest is paid in US$ out of the oil sales of that particular project. These payments have to be deducted from the gross dollar inflow to obtain the dollar inflow available for Iran, previously indicated by R$.

Iran's oil export is (XOIL) defined as oil production (QOIL) minus domestic demand (DOILD). Multiplying XOIL by the exogenously determined price of oil (POIL) yields the U.S dollar value of the oil revenues (OILR$). Note that oil production is a policy variable and exogenous. The domestic demand for oil is endogenously determined in the energy models discussed in subsections 6.3.2 and 6.3.3. So annual oil revenues are defined as:

$$OILR\$_t = (XOIL_t * 365 * POIL_t)/1000 \tag{6.9}$$

XOIL is measured in million barrels per day and OILR$ in billion US$ per year. XOIL is defined as:

$$XOIL_t = \overline{QOIL}_t - (DOILD_t/365) \tag{6.10}$$

$\overline{QOIL}$ is oil production in million barrels per day, and DOILD is the annual domestic demand in barrels. The government-owned National Iranian Oil Company (NIOC) is responsible for Iran's oil production and produces in compliance with the quota agreed upon within OPEC; see Chapter 3. Under normal circumstances Iran's position on the world oil market is relatively weak; thus it is impossible for Iran to influence oil prices other than through participation in the negotiations within OPEC.

Using Eq. (6.9) and taking into account the definition of the other variables the dollar inflow can be defined as:

$$R\$_t = OILR\$_t + NOIL\$_t + FDI_t - BE_t \tag{6.11}$$

All variables in this definition have been explained above, with the exception of BE_t. This variable stands for buyback expenditure, the value in US$ of crude oil foreign firms receive as compensation and profit in return for investing in projects under a formula that denies them a direct equity stake.

Consumer Price Index

In the model only one price variable is determined endogenously, the consumer price index (CPI). This measure of the domestic inflation is used to convert the nominal prices of energy carriers set by the government into real prices, which are major explanatory variables in the energy demand models. Basically the CPI equation is based on the quantity theory of money, which states that the growth in prices is equal to the growth in money supply minus the growth in the real economy, under the assumption that the velocity of money is constant. As was shown by Liu and Olumuyiwa (2000), reality is slightly more complicated. They developed a dynamic model of inflation, with inflation being a function of excess money supply, monetary growth, changes in exchange premium (difference between the parallel market rate), and the expected rate of inflation represented by lagged inflation rates. For annual data such an elaborate approach did not work. After some experimentation the following equation performed best. Note that satisfying results could only be obtained for the time period 1979-1998, that is the period after the Islamic revolution.

$$\begin{aligned} LOG(CPI) = {} & \underset{(299.1)}{5.181} + \underset{(73.7)}{1.149}*(LOG(LIQUID)-LOG(GDP)) \\ & + [\underset{(1.83)}{AR(1) = 0.235}] \end{aligned} \tag{6.12}$$

EM: OLS; $R^2_{adj} = 0.99$; DW = 1.01; ADF = -4.00*

LIQUID stands for quasi money, which is defined as money (M1) plus pseudo money (M2). Since GDP is a recursive variable in the overall model, the equation can be estimated by OLS.

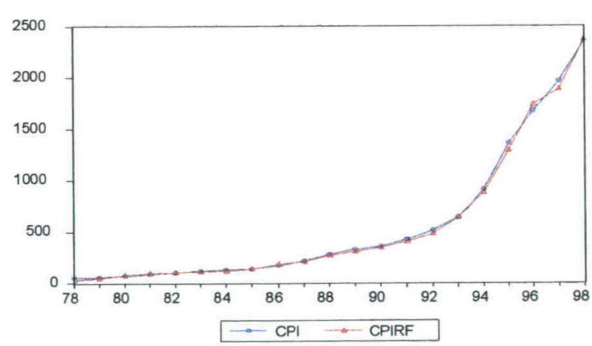

Figure 6-8. Simulated and actual trend of CPI

All coefficients are statistically highly significant. The unit root hypothesis on the residuals is rejected, supporting the hypothesis that the equation is cointegrated.

The effect of an increase in the LIQUID over GDP has an immediate larger effect on CPI, showing the dominant role of liquidity in the monetary sector of the Iranian economy. Later we will show that this also has a large effect on the domestic energy sector, when energy prices are not set in line with inflation.

6.3.2 Final Energy Demand Model

Final energy demand is the demand for energy products by the non-energy sectors, that is productive sectors such as industry, agriculture, services, and the consumption sectors such as households and commercials, and the government. In Iran the total demand for final energy is the combined demand for the following eight fuels: jet fuel, LPG, gasoline, kerosene, gas oil, fuel oil, natural gas, and electricity. Also solid fuels (mainly coal) are used in Iran, but their share in total energy supply is very small. Therefore, solid fuels are treated as an exogenous variable.

For each of the final energy demand equations the real price of the fuel as well as that of its main competitors was originally included in the specification of the fuel demand equations. None of the cross price elasticities was, however, statistically significant, which is no surprise since all real energy prices steadily decrease over most of the sample period. We will not report these findings. Surprisingly enough the own price elasticities turned out to be statistically significant, despite the extremely low real energy prices. For future policy simulation reasons we included the own real price of each fuel as an explanatory variable, despite the fact that some are not significant at he 95% level.

Next we discuss the demand equation for the eight energy carriers.

Jet Fuel

Since jet fuels (JETF) are mainly used for aviation transportation, the main variables affecting jet fuel consumption are the amount of cargo (LOADA) and the numbers of passengers (PASA) carried by aviation. Normally these two variables would be determined by income, but in Iran this is not the case. These variables are to a large extend based on the government's traveling policy for its employees and its cargo. Therefore, we can in addition add GDP as an explanatory variable. A time trend was added to indicate technical progress in aviation leading to a reduction in demand. The equation is in the log-log functional form and has been estimated by 2SLS.

$$LOG(JETF) = -10.64 + 0.14*LOG(PASA) + 0.54*LOG(LOADA) \quad (6.13)$$
$$\quad\quad (-5.6) \quad (1.04) \quad\quad\quad (2.27)$$

$$+ 1.07*LOG(GDP) - 0.05*TREND + 0.21*LOG(JETF(-1))$$
$$(2.80) \quad\quad (-4.3) \quad\quad (1.78)$$

EM: 2SLS; $R^2_{adj} = 0.91$; DW = 2.46; h-DW = -1.30; ADF = -3.20**

All coefficients are statistically meaningful except the coefficient for PASA, which rejects the null hypothesis only at the 70 percent level. The adjusted R-squared is 0.91, indicating a good fit, which is also supported by Figure 6-10. (Remember, the data in the figure are based on the simulation of the total model.) The estimated h-DW is -1.3, so the null hypothesis of first order serial correlation is rejected at the 95 percent level. The ADF test indicates that the equation is cointegrated, since it rejects the null hypothesis of a unit root in the residuals.

Changes in GDP have a large effect on JETF, 1.07 immediately and 1.35 in the long term. For LOADA these effects are much smaller, 0.54 and 0.68 respectively.

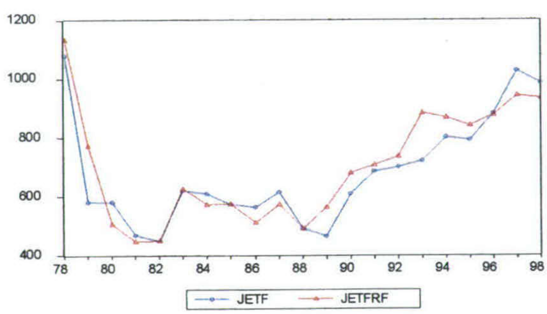

Figure 6-10. Simulated and actual trend of jet demand fuel in million liters

Remark: Originally equations for PASA and LOADA were also developed and estimated. Reasonable results were obtained, but these equations did not perform well in the simulation of the complete model. Therefore, these equations were omitted from the model.

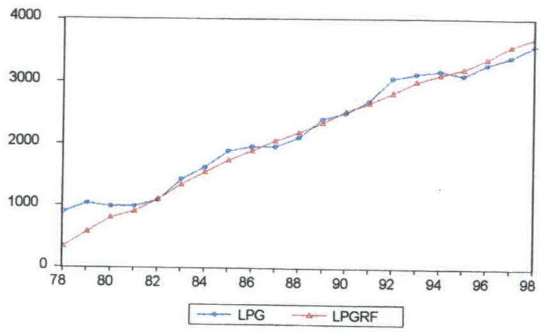

Figure 6-11. Simulated and actual trend in LPG demand in million liters

Liquefied Petroleum Gas

LPG is mainly used in the Residential and Commercial sector. There are several factors affecting the demand for LPG, including the development in the gas for oil substitution policy. However, the major factor is the increase in the number of households in rural areas and small cities. To measure this effect we use the number of rural households (NRHOUS). (Number of households rather than population, because there is a tendency for young people to leave the family home earlier and live independent.) The real price of LPG (RPLPG) is another variable that affects the demand for LPG. GDP is included to measure the income effect. The log-log functional form did not perform well for LPG. The best result that could be obtained is:

$$\begin{aligned} LPG = &- 1799.0 - 31.83*RPLPG + 0.00053*NRHOUS + 0.0618*GDP \\ &\quad (-1.96) \quad (-1.80) \qquad\quad (2.25) \qquad\qquad\qquad (2.81) \\ &+ 0.600*LPG(-1) \qquad\qquad\qquad\qquad\qquad\qquad\qquad (6.14) \\ &\quad (5.10) \end{aligned}$$

EM: 2SLS; $R^2_{adj} = 0.98$; DW = 1.77; h-DW = 0.90; ADF = -2.80***

All coefficients have the right sign and are statistically meaningful. With 98 percent the goodness of fit is very high; which also holds for the dynamic simultaneous simulation as is shown in Figure 6-11. The h-DW statistics indicates that the first order serial autocorrelation is rejected at the 95 percent level

Gasoline

The transportation sector is the main consumer of gasoline (GSLN). The stock of vehicles using gasoline (SGSCAR), the real price of gasoline (RPGSLN), and income measured through GDP are the main explanatory variables. Due to the 1980-1988 war between Iran and Iraq, gasoline was rationed in 1980, drastically limiting gasoline consumption, especially up till 1982. The rationing regime was abolished in 1986, allowing an increase in demand to a new higher level, but the main effect of the rationing policy took place in the first three years. Therefore, a dummy variable (DGSLN) is introduced, which has the value one 1 for the period 1980 to 1982, and is zero elsewhere.

$$
\begin{aligned}
LOG(GSLN) = &-4.429 - 0.024*LOG(RPGSLN) + 0.354*LOG(SGSCAR) \\
&(-2.9) \quad (-2.91) \qquad\qquad\qquad (4.3) \\
&+ 0.425*LOG(GDP) - 0.114*DGSLN \\
&(-1.8) \qquad\qquad\qquad (1.6) \\
&+ 0.483*LOG(GSLN(-1)) \qquad\qquad\qquad\qquad (6.15) \\
&(3.3)
\end{aligned}
$$

EM: 2SLS; $R^2_{adj} = 0.99$; DW = 2.1; h-DW = -0.28; ADF = -3.3**

The statistics show that this equation performs well on all criteria used.

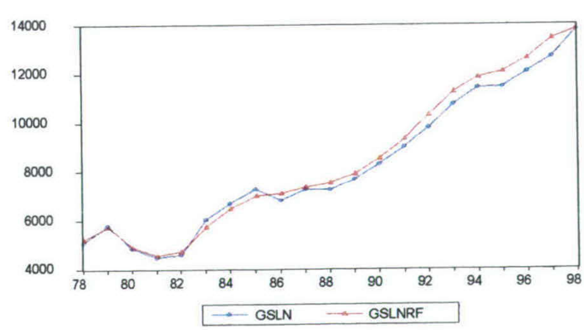

Figure 6-12. Simulated and actual demand for GSLN in million liters

The real price elasticity of gasoline demand is rather small (–0.024), but significant; as is the long-term effect (-0.045). What is surprising, given our analysis of energy prices in Chapter 2, is the fact that there still is an effect. The short and long term effects of SGSCAR and GDP are (0.36; 0.68) and (0.43; 0.81) respectively.

To complete the model for gasoline demand an equation for the stock of vehicles is added.

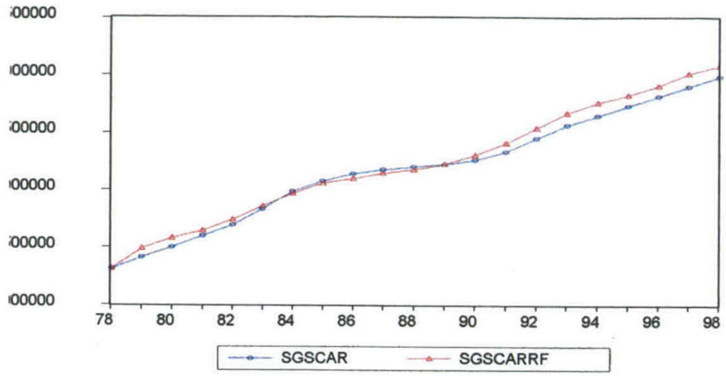

Figure 6-13. Simulated and actual number of gasoline consuming cars

Sub-model for the stock of vehicles

The stock of the vehicles using gasoline (SGSCAR) is a function of economic activity, which is indicated by GDP. Increases in the level of GDP make money available for new vehicles, which in turn increases the total mileage required, resulting in an increase in the demand for gasoline. The estimation result is:

$$\begin{aligned} \mathrm{LOG(SGSCAR)} = & \underset{(-0.60)}{-0.371} + \underset{(6.55)}{0.214}{*}\mathrm{LOG(GDP)} - \underset{(-2.53)}{0.005}{*}\mathrm{TREND} \\ & + \underset{(38.36)}{0.894}{*}\mathrm{LOG(SGSCAR(-1))} \end{aligned} \tag{6.16}$$

EM: 2SLS; $R^2_{adj} = 0.99$; DW = 2.42; h-DW = -1.03; ADF = -2.9**

The statistics indicate that this equation meets all criteria. The negative trend indicates the technical depreciation of the stock. The short and long-term elasticities for GDP are 0.214 and 2.019 respectively, indicating that a car as a durable good is high on the agenda. Furthermore, during the war period and shortly thereafter, it was difficult to purchase new cars, but a dummy variable was not significant.

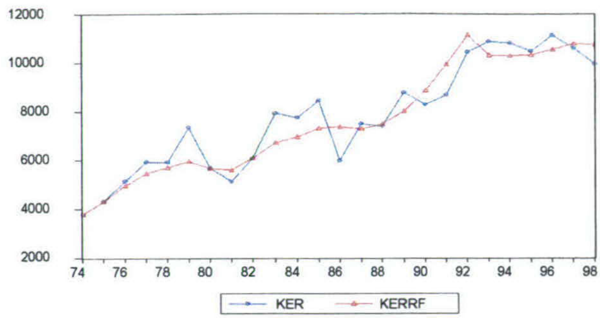

Figure 6-15. Simulated and actual trend of KER in million liters

Kerosene

Kerosene is mainly consumed in the Residential and Commercial sector for cooking and heating purposes, especially in rural areas and small cities. The demand for kerosene (KER) is modeled as a function of its own real price (RPKER) and the real gross domestic product (GDP).

$$\underset{(-0.10)}{\mathrm{LOG(KER)} = -0.14} - \underset{(-2.53)}{0.143}*\mathrm{LOG(RPKER)} + \underset{(3.20)}{0.616}*\mathrm{LOG(GDP)} +$$

$$+ \underset{(2.61)}{0.381}*\mathrm{LOG(KER(-1))} \qquad (6.17)$$

EM: 2SLS; $R^2_{adj} = 0.84$; DW = 2.33; h-DW = -1.32; ADF=-3.4**

All coefficients are statistically meaningful. The estimated h-DW rejects the null hypothesis of the first order serial correlation. The goodness of fit is less than in the previous equations, but still acceptable. Figure 6-15 shows that the simulated variable captures the trend in the data.

The short and long term own real price elasticities of kerosene demand are -0.143 and -0.231 respectively. Given Iran's energy pricing policy these effects are remarkably high, although they are small compared to the income elasticities: 0.616 and 0.995 respectively.

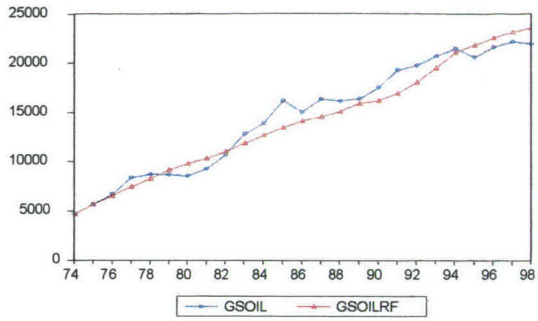

Figure 6-16. Simulated and actual trend of GSOIL in million liters

Gas Oil

Gas oil is mainly used in transportation for vehicles carrying cargo and passengers. However, a considerable amount of gas oil is used by the Residential and Commercial sector also for heating purposes. Because of the natural gas for oil substitution policy, the consumption of gas oil is declining over the time. The following result was obtained:

$$\text{LOG(GSOIL)} = \underset{(0.14)}{0.115} - \underset{(-0.79)}{0.069}*\text{LOG(RPGSOIL)} + \underset{(2.10)}{0.221}*\text{LOG(GDP)}$$

$$+ \underset{(6.30)}{0.781}*\text{LOG(GSOIL(-1))} \qquad (6.18)$$

EM: 2SLS; R^2_{adj} = 0.98; DW = 1.83; h-DW = -0.61; ADF = -3.90*

All coefficients are significant, except the one for the real price of gas oil. The h-DW rejects the null hypothesis of first order serial correlation at the 95 percent level. The null hypothesis of the unit root test on the residuals is rejected. Figure 6-16 shows that the simulation of the equation performs well.

The own real price elasticity of demand is low (-0.067), but is still minus 0.31 in the long run. The immediate income effect as measured by GDP is 0.221, and in the long run the effect is almost one.

Fuel Oil

Fuel oil (FOIL) is mainly used in the industrial sector. It is affected by economic activity, measured by the GDP, and by the real price of fuel oil (RPFOIL).

$$\begin{aligned} LOG(FOIL) = \underset{(1.32)}{1.579} - \underset{(-1.70)}{0.154}*LOG(RPFOIL) + \underset{(1.02)}{0.213}*LOG(GDP) \\ + \underset{(3.50)}{0.598}*LOG(FOIL(-1)) \end{aligned} \qquad (6.19)$$

EM: 2SLS; $R^2_{adj} = 0.94$; DW = 1.78; h-DW = 0.55; ADF = -3.40**

This equation is rather weak, with the explanatory variables barely significant. Figure 6-17 shows that the simulation of fuel oil demand follows the trend in the data reasonably well in the beginning of the sample period, but that the deviations become larger towards the end of the sample period. This might be due to the gas for oil policy executed by the government, which becomes more effective towards the end of the period.

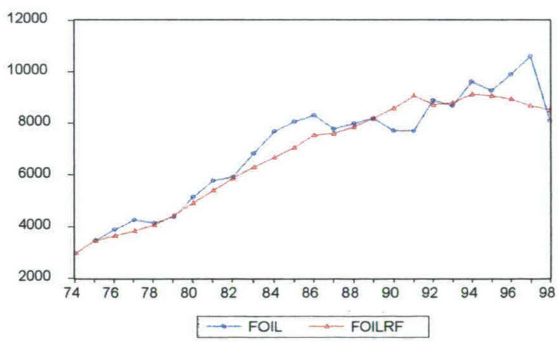

Figure 6-17. Simulated and actual demand of fuel oil in million liters

Equation (6.19) indicates that the short run own price elasticity of demand is -0.154 and that the income elasticity is more than 0.213; the long run elasticities are -0.383 and 0.529 respectively.

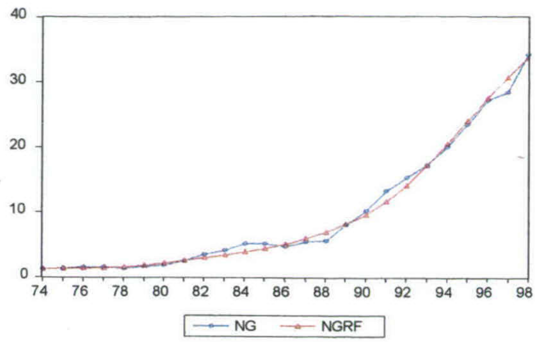

Figure 6-18. Simulated and actual trend of NG in billion cubic meters

Natural Gas

Natural gas is used in many sectors of the economy, but the main consuming sectors are residential and commercial, and industry. The market for natural gas in Iran is still incomplete and its development is one of the major energy policies of the energy authorities of Iran; also see Chapter 4. To measure the effect of the gas for oil substitution policy we use the number of natural gas consumers (NNGC). Also the real price of natural gas (RPNG) is used as an explanatory variable. A natural gas equation that performed well in the complete model could only be obtained using a linear functional form instead of the log linear form.

$$NG = 0.650 - 0.0523*RPNG + 3.005e\text{-}06*NNGC + 0.759*NG(-1) \qquad (6.20)$$
$$(1.01) \quad (-0.24) \qquad (1.81) \qquad (3.69)$$

EM: 2SLS; $R^2_{adj} = 0.99$; DW = 1.97; h-DW = 0.36; ADF = -2.9***

As expected, the coefficient of the real price of natural gas is insignificant. Since real prices will play an important role in the policy scenarios to come, it is, however, included in the equation. The other statistics meet the criteria set.

Electricity

Electricity demand (ELEC) is the last final energy demand category modeled. It is modeled as a function of the real price of electricity (RPELEC) and the number of electricity customers (NELECC) as a measure of market development. Unfortunately RPELEC has a perverse effect on the demand for electricity, although not significant.

Therefore, we fixed the coefficient of RPELEC on -0.041, to have at least some effect of RPELEC on ELEC. (The value of -0.041 is based on results for shorter estimation periods.) The equation is estimated using the OLS technique and the result is:

$$
\begin{aligned}
LOG(ELEC) = 0.469 - 0.041{*}LOG(RPELEC) &+ 0.191{*}LOG(NELECC) + \\
(2.20) \qquad\qquad\qquad &\qquad (1.44) \\
+ 0.803{*}LOG(ELEC(-1)) & \qquad\qquad\qquad\qquad (6.21) \\
(7.50) \qquad\qquad\qquad &
\end{aligned}
$$

EM: OLS; $R^2_{adj} = 0.99$; DW = 2.13; h-DW = -0.36; ADF = -3.45**

Although Eq. (6.21) has a good fit, it is obviously not a good equation since its strength mainly depends on the lagged endogenous variable. Unfortunately, better results could not be obtained.

The short and long term elasticities for RPELEC and NELECC are -0.04 and 0.19, and –0.20 and 0.96 respectively.

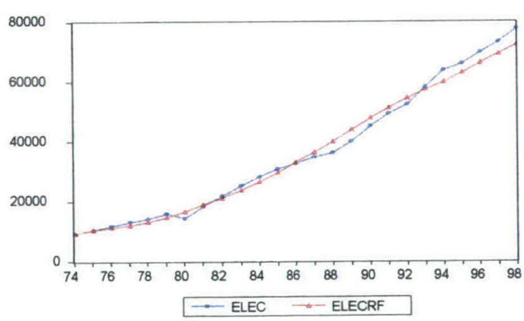

Figure 6-19. Fitted and actual trend of ELEC in million kWh

Number of Electricity Consumers

Iran's electricity market is going to be completed soon and only a few remote villages will not be connected to the national integrated grid. The number of electricity customers (NELEC) was and will be affected by the dynamics in the number of households (NHOUS) demanding electricity, especially in the urban areas.

$$
\begin{aligned}
LOG(NELECC) = 0.543 + 0.943{*}D(LOG(NHOUS)) + \\
(7.4) \qquad (1.4) \qquad\qquad\qquad
\end{aligned}
$$

$$+ 0.944*LOG(NELECC(-1)) \qquad (6.22)$$
$$(13.5)$$

EM: OLS; $R^2_{adj} = 0.99$; DW = 1.41; h-DW = 1.4; ADF = -4.9*

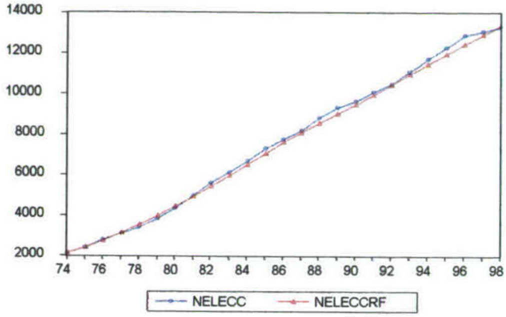

Figure 6-20. Simulated and actual trend of NELECC in thousands

Solid fuels

Solid fuels include hard coal, charcoal, wood, and the other non-commercial energy carriers. Together this diverse set of fuels has only a small share in Iran's total energy basket. Its annual consumption is around 10 million BOE. Therefore, the demand of solid fuels is treated as an exogenous variable assuming one percent growth rate annually.

$$\mathrm{SOLID}_t = 1.01 * \mathrm{SOLID}_{t-1} \qquad (6.23)$$

Nominal Price of Energy

The nominal price of energy (PENG) is the weighted average of the nominal prices of energy carriers set by the government. The weights are the share of each energy carriers in total final energy demand. Since the price of solid fuels is not available and the share of solid fuels is small, it is ignored in the average price of energy. All values in the equation are per barrel of oil equivalent (BOE), which is indicated by B at the end of each variable. P*i* indicates prices and *i*B quatity.

$$\mathrm{PENG} = \frac{\sum_{i \in I} \mathrm{P}i\mathrm{B} * i\mathrm{B}}{\mathrm{TFEDB} - \mathrm{SOLIDB}} \qquad (6.24)$$

with $i \in$ {JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC}.

Total Final Energy Demand

Total final energy demand in million BOE (TFEDB) can be obtained by using the conversion factors in the table below to convert each unit to MBOE.

Energy carrier	Unit reported	Conversion factor for bbl
JETF	million liters	$6.036/10^3$
LPG	million liters	$4.166/10^3$
GSLN	million liters	$5.525/10^3$
KER	million liters	$5.928/10^3$
GSOIL	million liters	$6.189/10^3$
FOIL	million liters	$6.502/10^3$
NG	billion cubic meters	6.388
ELEC	million kWh	$630.38/10^6$

Note that in the calculation of TFEDB all variables are expressed in MBOE. Figure 6-22 contains the simulated and actual data for TFEDB.

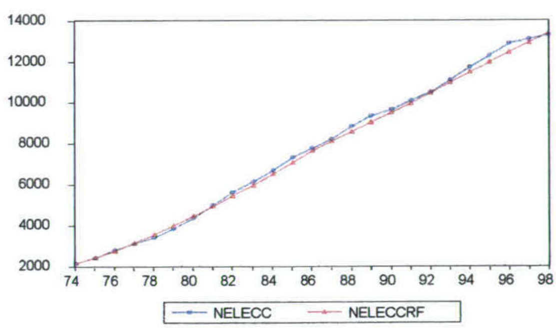

Figure 6-22. Simulated values for TFEDB in MBOE

6.3.3 Primary Energy Demand Model

In the previous subsection final energy demand was discussed. This subsection discusses the primary energy demand model, which contains two sectors of the economy, power generation and refineries. These two sectors are part of the government, Furthermore, prices do hardly play a role in the decision making process of these sectors, only fuel availability important. Finally, the prices for these large consumers are not recorded. Therefore, fuel prices will not occur as an explanatory variable in the primary demand model. Note that the prices of final demand do, however, affect primary demand through their effects on the demand for final energy carriers.

Power generation

All final demand for electricity (ELEC) is generated by the power sector using either thermal power or hydropower plants. The amount of electricity produced in thermal power plants is denoted by QTEG and the amount of electricity produced in hydro power plants by HEG.

The Iranian power sector is rather inefficient. During the process of distribution and transmission about 15% of the electricity produced is lost. Furthermore, own consumption by power plants is 5% of gross electricity. Adding losses and self-consumption to final demand results in gross electricity generation (GEG) needed for end-use consumption. Let EF denote the efficiency factor -which is thus equal to 0.8-, then GEG can be obtained by dividing ELEC by EF; see Eq. (6.26).

Next we need to know how much of GEG is produced by thermal power plants and how much by hydro plants. We will model this by subtracting the development in hydropower production from gross requirements. Iran's hydro potential is about 42,000 megawatt, but only 5 percent of this potential is used. The historical data show that the share of hydro (SH) in total gross electricity generation (GEG) has been decreasing. Also there are no plans to tap Iran's hydro potential in the near future. It is assumed that this trend will continue; the share of hydro in year t is set at 99 percent of that of year t-1. All this results in:

$$GEG_t = \frac{ELEC_t}{EF} \tag{6.25}$$

$$HEG_t = 0.99 SH_{t-1} GEG_t \tag{6.26}$$

$$SH_t = \frac{HEG_t}{GEG_t} \tag{6.27}$$

The demand for thermal electricity generation is obtained by subtracting HEG_t from GEG_t; that is:

$$QTEG_t = GEG_t - HEG_t = (1-SH_t)GEG_t \tag{6.28}$$

Note that EF is determined exogenously. When analyzing the opportunities for energy efficiency improvement, this efficiency coefficient shall be adjusted. Finally, the overall efficiency of Iran's thermal power plants has been rather stable in the past and around 37%.

Next we will estimate demand equation for fuel oil, gas oil and natural gas for the power sector using QTEG as the major explanatory variable.

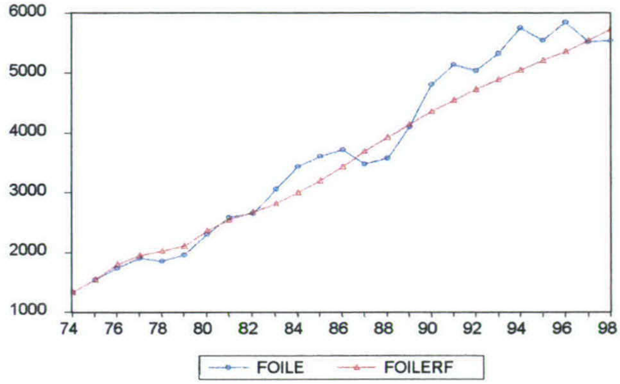

Figure 6-23. Simulated and actual values of FOILE in million liters

Fuel oil in thermal power generation

The demand for the fuel oil by the power sector (FOIE) as a function of the quantity of electricity generated in the thermal power plants is estimated by using the 2SLS method.

$$\begin{aligned} LOG(FOILE) = {} & \underset{(3.20)}{1.435} + \underset{(2.45)}{0.396}*LOG(QTEG) + \underset{(3.20)}{0.755}*LOG(FOILE(-1)) \\ & \underset{(-2.10)}{-\,0.435}*LOG(FOILE(-2)) \end{aligned} \tag{6.29}$$

EM: 2SLS; $R^2_{adj} = 0.98$; DW = 1.7; ADF = -3.6**

All coefficients are significant at the 95 percent level. The hypothesis of first order autocorrelation is rejected. The simulation of the trend in the data in the total model is acceptable as is shown in Figure 6-23.

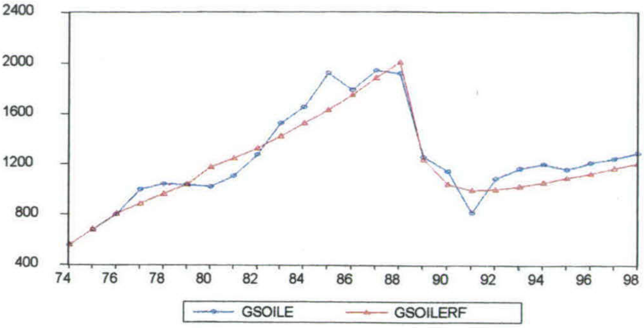

Figure 6-24. Simulated and actual trend of GSOILE in million liters

Gas oil in thermal power generation

The demand for gas oil by the power sector (GSOILE) is considered as a function of thermal electricity production (QTEG). However, the demand for gas oil by the power sector is also affected by the gas for oil substitution policy for the power sector, which started in 1991. This is introduced through the use of a dummy variable (DGSOIL), which is one for the years of 1991-1998 and zero elsewhere. Note that this dummy plays a role in the demand for gas oil and not in the demand for fuel oil, since fuel oil is relatively cheap and substitution aims at the more expensive gas oil.

$$\begin{aligned} \text{LOG(GSOILE)} = \underset{(1.39)}{0.650} &+ \underset{(5.3)}{0.351}\text{*LOG(QTEG)} - \underset{(-6.2)}{0.540}\text{*DGSOILE} \\ &+ \underset{(4.91)}{0.430}\text{*LOG(GSOILE(-1))} \end{aligned} \qquad (6.30)$$

EM: 2SLS; $R^2_{adj} = 0.90$; DW = 2.57; h-DW = -1.51; ADF=-3.16*

All coefficients are significant at the 99 percent level. The hypothesis of first order autocorrelation is rejected, using the h-DW statistics. Figure 6-24 shows that the simulated values in the overall model are close to the actual values.

Natural gas in power generation

The demand for natural gas by the power sector (NGE) is a function QTEG and the policy dummy DGSOILE. It is estimated by 2SLS since the thermal electricity generation is determined endogenously.

$$LOG(NGE) = -2.898 + 0.328*LOG(QTEG)+0.725*LOG(NGE(-1)) \quad (6.31)$$
$$(-1.20) \quad (1.31) \quad (4.18)$$

EM: 2SLS; $R^2_{adj} = 0.98$; DW = 1.9; h-DW = 0.53; ADF = -3.76**

This equation is rather weak and the coefficient of QTEG is only significant at the 80 percent level. Based on the h-DW statistics, the first order autocorrelation is rejected. The equation has a good fit, but the simulated values in the overall model are slightly below the actual values; see Figure 6-25.

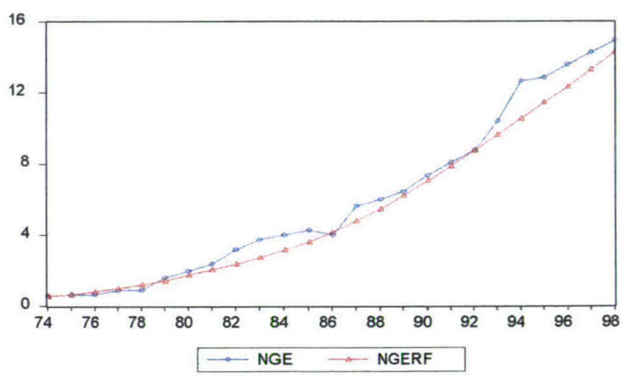

Figure 6-25. Simulated and actual trend of NGE in billion m^2

Oil Refineries

The gross demand for oil needed by the refinery sector to produce the final demand for petroleum products can be estimated through the use of a technical coefficient, which transforms crude oil into its composite products. Table 6-1 contains some historical data that show that Iranian refineries have transformed one barrel of crude oil into 0.87-0.89 composite barrels of petroleum products. In other words, to obtain one composite barrel of petroleum products about 1.14 barrel of crude oil is required. Note that this includes own consumption and losses during the refining process, which are in Iran about 7% of the total crude oil feed, 2% higher than normal practice elsewhere.

The factor of 1.14 will be used to calculate the amount of crude oil needed to produce the required amount of petroleum products. The factor is treated as a constant since the number of refineries in Iran has not changed for some time. We assume that for the future the composition remains constant. When estimating the potential for energy savings in Chapter 7, this factor shall be adjusted due to increased efficiency.

Table 6-1. Input-Output ratio of Iranian petroleum refinery

Year	Crude oil feed	Petroleum Products	Output/input ratio
	Million bbl/day	Million bbl/day	%
1995	1.3	1.2	0.89
1996	1.4	1.2	0.87
1997	1.5	1.3	0.87
1998	1.5	1.4	0.88

Source: Energy Balance of Iran, Energy Ministry, 1999.

The total demand for petroleum products is the sum of the final demand for petroleum products plus the demand for fuel oil and gas oil by the power sector. Using the conversion factors introduced before to transform final demand from liters to MBOE, we can write

$$\mathrm{TPPC}_t = \sum_{i\in\{\mathrm{JETF,LPG,GSLN,KER,GSOIL,FOIL}\}} i\mathrm{B}_t 10^{-3} + (\mathrm{GSOILEB}_t + \mathrm{FOILEB}_t)10^{-3} \tag{6.32}$$

TPPC stands for total petroleum product consumption in million composite barrels. The domestic demand for oil (DOILD) can be obtained as:

$$\mathrm{DOILD}_t = 1.14\,\mathrm{TPPC}_t \tag{6.33}$$

Total natural gas demand

Total natural gas demand is the sum of final demand consumption (NGC), demand for power generation (NGE), to which gas used in petroleum refineries (NGR) has to be added. This is the total amount of natural gas required at the beginning of natural gas network. A proportion of that gas is lost during transportation and data for 1998 show that this is about 0.58 percent of total natural gas demand. Furthermore, about 4.46

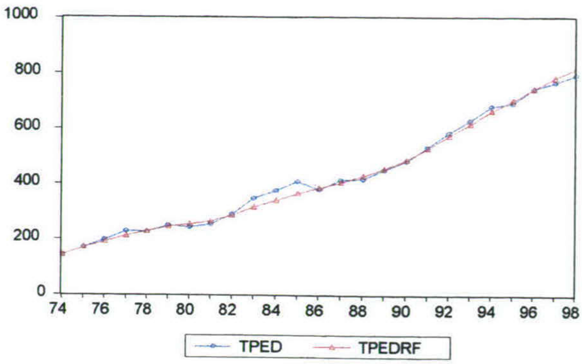

Figure 6-26. Simulated and actual TFPEDB in MBOE

percent is own consumption for operating the network. The amount of natural gas that has to be delivered to the network (NGT) is considered the primary demand for natural gas, and is calculated as:

$$NGT_t = 1.0504\ (NGC_t + NGE_t + NGR_t) \quad (6.34)$$

The natural gas demanded by oil refineries is a based on a technical relation and can be modeled as a fraction the daily demand of oil feed for refineries; that is:

$$NGR_t = 0.87(DOILD_t/365) \quad (6.35)$$

Note that NGT can be transformed into MBOE via the conversion factor of Table 6-1; that is $NGTB_t = 6.388*NGT_t$.

Total Primary Energy Demand

The following identity calculates total primary energy demand measured in MBOE (TPEDB).

$$TPEDB_t = DOILDB_t + NGBT_t + SOLIDB_t + HEGB_t \quad (6.36)$$

Figure 6-26 shows the simulated and actual data of TPEDB. From this figure we can conclude that the model simulation over the estimation period is accurate.

6.3.4 Energy Subsidies on Final Energy Demand

As was already discussed in Chapter 3, each of the eight energy carriers distinguished has its own border and domestic price. The difference between these two is the subsidy per unit of that particular energy carrier. The subsidy per energy carrier is $Si_t = \left(PBi_t - \dfrac{Pi_t}{ER_t} \right) Di_t$, with $i \in$ {JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC} and Di_t the final demand for energy carrier i.

The domestic energy prices -set by the government in Rial- are evaluated at their dollar value by using the free market exchange rate (ER). Total subsidy is defined as:

$$\text{SUBSID}_t = \sum_i Si_t \tag{6.37}$$

In Chapter 2 the data for the border prices were obtained. For the future these are linked to the development in the international oil price; see next section.

To estimate subsidies the free market exchange rate (ER) is needed. This variable is therefore also made endogenous. ER is modeled as a function of inflation (CPI) and the dollar inflow (R$). Increases in domestic inflation will increase the exchange rate, thus depreciate the value of the national currency Rial. The dollar injection has an opposite effect; more dollar inflow will strengthen the value of the Rial. The estimated equation is:

$$\begin{aligned} \text{LOG(ER)} = {} & \underset{(3.03)}{1.670} + \underset{(2.83)}{0.386}\text{*LOG(CPI)} - \underset{(-2.51)}{0.368}\text{*LOG(R\$)} + \\ & + \underset{(4.47)}{0.606}\text{*LOG(ER(-1))} \end{aligned} \tag{6.38}$$

EM: OLS; $R^2_{adj} = 0.98$; DW = 2.05; h-DW = -0.15; ADF = -2.9***

The equation meets the statistical criteria set. A one percent increase in CPI leads to 0.386 percent increase in the ER in the short term and 1.135 percent in the long term. The effect of the dollar inflow is only marginally smaller -0.368 percent in the short term and approximately one percent in the long run. This again (also see CPI) shows the importance of Iran's monetary policy and how sensitive the nominal part of the economy is.

Table 6-2. Dynamic simulation performance overview

Variable	Correlation	Theil coef.	Mean Data	Mean Simul.	Ratio	Standard deviation Data	Standard deviation Simul.	Ratio
AERC	0.960	0.011	4.806	4.776	1.006	0.305	0.360	0.846
CPI	0.995	0.012	5.664	5.614	1.009	1.207	1.254	0.962
CP	0.977	0.003	8.891	8.899	0.999	0.217	0.216	1.009
DOILD	0.988	0.004	5.771	5.746	1.004	0.288	0.291	0.992
ELEC	0.991	0.004	10.494	10.474	1.002	0.551	0.569	0.968
ER	0.991	0.017	6.911	6.778	1.020	1.141	1.251	0.912
FOILE	0.982	0.007	8.245	8.155	1.011	0.367	0.329	1.117
FOIL	0.948	0.005	8.913	8.880	1.004	0.256	0.252	1.016
GDEM82	0.972	0.003	9.388	9.407	0.998	0.213	0.221	0.962
GDPM82	0.972	0.002	9.434	9.452	0.998	0.184	0.189	0.974
GEG	0.991	0.004	10.701	10.681	1.002	0.547	0.566	0.966
GSLN	0.997	0.002	8.958	8.981	0.997	0.349	0.363	0.960
GSOILE	0.915	0.009	7.159	7.072	1.012	0.239	0.221	1.084
GSOIL	0.968	0.004	9.640	9.616	1.002	0.333	0.319	1.041
G	0.949	0.005	7.482	7.530	0.994	0.189	0.191	0.992
HEG	0.658	0.039	8.840	9.370	0.943	0.162	0.566	0.286
I	0.854	0.009	7.567	7.627	0.992	0.249	0.222	1.124
JETF	0.922	0.008	6.490	6.516	0.996	0.259	0.272	0.953
KER	0.915	0.006	9.003	8.991	1.001	0.241	0.246	0.980
LPG	0.955	0.017	7.598	7.501	1.013	0.472	0.653	0.723
M	0.767	0.016	7.002	7.008	0.999	0.354	0.246	1.437
NELECC	0.999	0.001	8.986	8.973	1.001	0.417	0.404	1.031
NGE	0.985	0.067	1.692	1.497	1.130	0.790	0.761	1.038
NG	0.992	0.028	2.000	1.992	1.004	0.999	0.988	1.011
NGT	0.993	0.022	2.650	2.595	1.021	0.894	0.865	1.033
OILR$	0.997	0.005	2.646	2.656	0.996	0.288	0.292	0.987
PENG	1.000	0.002	7.912	7.920	0.999	0.918	0.909	1.010
QTEG	0.990	0.009	10.508	10.367	1.014	0.642	0.566	1.134
R$	0.998	0.004	2.793	2.802	0.997	0.288	0.290	0.994
SGOCAR	0.997	0.001	12.749	12.759	0.999	0.250	0.250	0.996
SGSCAR	0.996	0.001	14.570	14.591	0.999	0.241	0.244	0.986
TPED	0.994	0.004	6.086	6.067	1.003	0.406	0.410	0.992
TPPC	0.988	0.004	5.640	5.615	1.004	0.288	0.291	0.992
XOIL	0.998	0.015	0.677	0.687	0.985	0.404	0.407	0.993
X	0.967	0.007	7.599	7.578	1.003	0.406	0.428	0.948

As a final evaluation of the model presented above we give an overview of the correlation coefficients between the data and the simulated data together of the overall SE model and Theil's inequality coefficient. For a review of the model we refer to Appendix A and for a list of variables to Appendix B.

6.3.5 Additional Performance Measures

The development of scenarios for policy analysis requires a sound simulation of the model developed in this section. As a final check we calculate for each variable the correlation coefficient between the simulated and the actual data, the ratios of their means and standard deviations, and Theil's inequality coefficients; see Table 6-2.

Theils' inequality coefficient is defined as (Pindyck and Rubinfeld, 1998, p. 210)

$$U = \frac{\sqrt{N^{-1}\sum_{n=1}^{N}(Y_n^S - Y_n^A)^2}}{\sqrt{N^{-1}\sum_{n=1}^{N}(Y_n^S)^2} + \sqrt{N^{-1}\sum_{n=1}^{N}(Y_n^A)^2}}$$

N is the evaluation period, and Y_n^S and Y_n^A are the simulated and actual data respectively. In case of a perfect fit U is zero, and the upper bound for U is one; values for U smaller than 0.4 are considered acceptable.

Table 6-2 shows that for all endogenous variables the correlation between the actual and simulated data is high, that the calculated Theil-inequality coefficients are small, and that the mean and the standard deviation of the actual and the simulated data are close to each other (see columns Ratio). This final check makes us confident that the model can be used for scenario analysis for the time period 1999-2020.

Note that statistical tests could have been developed to support the conclusions drawn from Table 6-2. However, since such tests would, among others, depend on the estimated parameters and the estimation method used, this would be a cumbersome task. Since the results of our "eyeballing" approach give no reason to further substantiate our conclusions, statistical testing is omitted.

6.4 The Reference Scenario

The goal of this research is to determine the reduction potential of domestic energy consumption for the period of the 1999-2020. For this it is necessary to formulate a scenario that represents the case without any policy changes, further referred to as the reference case. In Subsection 6.4.1 the values for the exogenous variables are discussed. Subsection 6.4.2 discusses the reference scenario based on the assumptions formulated in Subsection 6.4.1.

6.4.1 Values for the Exogenous Variables

For this, assumptions on the values of the exogenous variables up to the year 2020 have to be formulated. The exogenous variables can be classified into four categories: dummy variables, demographic variables, money and price variables, and others. (An overview of all the assumptions discussed below is in Table 6-5.)

- *Dummy variables* used to account for extraordinary occurrences, such as the fuel shortages at the start of the war with Iraq. For each dummy variable a values have to be established. Luckily the model contains only three dummy variables: DGDE, DGSLN, DGSLOILE. Of these three only the dummy for the oil for gas substitution policy (DGSOILE) is 1 for the period 1999-2020, since the Iranian government will continue this policy.
- *Demographic variables* comprise population (POP), the number of households (NHOUS), and the number of rural households (NRHOUS). The average annual growth rate of Iran's population between 1974 and 1998 was about 2.8%. Compared to most countries, especially industrialized countries, this growth figure is very high. However, due to Iran's population policy, the growth rate has declined to an average of about 2 % for the last decade. Birth control and health training programs, as a part of the latest 5-year development plans, along with the economic pressure on households due to Iran's slow economic growth, have lowered the population growth rate even further. The most recent figure on the birth registration indicates a growth rate of 1.65% per year and this figure is expected to go down even further. The average growth rate for POP is therefore set at 1.5% per year.

The growth rate of the number of rural households was 1.3% over the sample period, but reduced to 1.1% over the period 1988-1998. This is partly due to the decrease in population growth and partly to the urbanization process that is going on. On the other hand the traditional living style of one big family in one household is abolished and young people start their own household. This results in an upward trend in the number of households. This is especially true for cities and urbanized areas. The overall affect is an increase in the number of households. Based on this we assume that the growth rate of NRHOUS is 1.1% and that of NHOUS 2%.

- *Money and price variables* comprise the domestic nominal final demand energy prices (PJETF, PLPG, PGSLN, PKER, PGSOIL, PFOIL, PNG, PELEC), liquidity (LIQUID), foreign direct investment (FDI), the import of capital goods (CAPIM$), non-oil export revenues (NOILR$), and the crude oil price (POIL). The future values of these variables for the reference case are based, as far as possible, on their past performance.

Developing scenarios for the economic exogenous variables is the most difficult part. The main problem is that the macro economic exogenous variables, for example liquidity and nominal energy prices, are to some extend interrelated. Therefore, the formulation of scenarios has to be done with care.

Table 6-4. Average annual growth rate of some economic variables

Period	Variable	1974-98	1988-98	1995-98
Liquidity	LIQUID	22.3%	23.9%	23.2%
Inflation	CPI	18.4%	21.4%	18.4%
Energy price*	PENG	14.4%	21.4%	23.8%
Capital goods import	CAPIM$	5.2%	9.2%	30.8%

* Weighted average

Table 6.4 contains the growth rates of some economic variables for three time periods 1974-1998, 1988-1998, and 1995-1998. During the post-war period of 1988-1998, the Iranian economy showed some improvement (World Bank, 2000). This is clearly indicated the high growth rate of CAPIM$ for the period 1995-1998. On the other hand, this high growth rate cannot be continued, because this would require more than the dollar inflow towards the end of the simulation period. For CAPIM$ we therefore assume an annual growth rate of 5% until 2020.

Liquidity growth has been high (see Table 6-4), and, without a change in domestic energy policy, will remain high in the future. The Iranian government wants to decrease the growth in liquidity, because it destabilizes the economy. However, we assume that the government is to some extend successful and able to reduce the growth rate of LIQUID to an average of 15% per year. Although this assumption is to some extend rather arbitrary and cannot be further substantiated, the actual assumption is not that important since the monetary sector is not part of our model. Note that this assumption does, however, strongly affect our real prices of energy, since it plays a dominant role in the equation for CPI.

The weighted average of the annual nominal energy price was 14.4 percent during the period of 1974-1998. During the final years of the sample period the largest changes occurred, which are related to the Second Five-Year plan. During this plan energy prices were on average raised by about 20 percent per year. However, these price increases have been strongly criticized in the Iranian parliament and became a political issue. For the 3rd five-year plan (1999-2005), ratified by the Iranian parliament, it is agreed that the increase in the energy price will not exceed 10 percent per year. We therefore assume that the increase in the nominal domestic energy prices will be 10 percent per year in the reference case.

Non-oil revenues and direct foreign investment are expected to grow according to their past levels of 5% per year each. The current level of non-oil export in year 2001 is estimated at 4.8 billion US dollar.

An important input for our analyses is the price of oil. Forecasting oil prices is notoriously difficult problem (Huntington, 1994; Stevens, 1996). Most model-based and judgmental forecasts have been too optimistic, forecasting large price increases. These were based on the belief that oil demand would rapidly outgrow supply. However, supply has been able to keep up and new more efficient technologies have lowered the growth in demand. Therefore, assumptions on long-term oil price development have been tempered, and the one used here will be moderate too.

The oil price in the IEA's 2020 outlook is assumed to grow to 21 dollar per barrel till 2010 and 28 dollar per barrel by 2020 (IEA, 2001). This price is the average the cost of crude oil import for IEA countries. In general, the price of 21 dollar per barrel exceeds the full costs of oil production for the new projects outside the Middle East OPEC area. Full-cycle costs comprise capital and operating costs, including an acceptable rate of return on investment for the oil companies. In the second decade, the gradual rise in oil prices to 28 dollar per barrel is consistent with the maturing and leveling-off of the non-OPEC production (IEA, 2001). For this study this oil price scenario is used as a starting point.

The U.S. Department of Energy on the other hand uses a price of 24.68 US$ per barrel in 2020 for its reference scenario and a price of US$ 30.58 for its high price scenario (DOE/EIA, 2001). Many experts do, however, find the DOE/EIA's reference scenario rather pessimistic.

OPEC tries to keep current oil prices in the range 22-28 US$ and expects the average production cost outside OPEC to grow till at least 26 US$ per barrel by the year 2020. Gately (2001) compares several scenario's and shows that prices will strongly depend on the increase in supply by the OPEC members.

Iranian oil is slightly cheaper than the average oil due to quality differences. The average differential between the crude oil import cost of IEA countries and the Iranian oil (light and heavy average) was about $1.5 per barrel during the period 1988-1998. Since the price assumptions by the various institutes differ, we use the IEA forecast for 2020 (28 US$/bbl) minus 1.5 US dollar as our assumption on the average Iranian oil price in 2020. We have chosen the IEA forecast because this forecast is in line with unpublished OPEC studies and the EIA reference scenario seems rather pessimistic. We use the value of 22 US$/bbl in the year 2000 as a starting point, and assume that this price will grow by a bit less than 1% per year to reach 26.50 US$/bbl in 2020. Note that our price assumption is, according to Gately's analysis, in line with a growth rate in OPEC's output between 2% and 3%.

- There are four other exogenous variables: oil production (QOIL), airline cargo (LOADA) and passengers ((PASA), and the number of natural gas customers (NNGC).

The level of Iran's oil production capacity has been the subject of several studies and experts tend to disagree on the potential capacity available. The IIES (1998) showed, however, that Iran's oil production capacity would decline quickly if no new oil fields were developed. This is because Iran's major oil fields passed the peak production in their life cycles. Since no untapped resources of similar size are available, Iran's level of oil production cannot be increased drastically. (Although improvement in technology might increase the potential of existing fields.)

The Petroleum Engineering and Development Company, an affiliation of the NIOC, has shown that the amount of oil that can be economically produced from new developments and redevelopments will not exceed 1.029 million-barrel per day during the next ten years (PEDC, 2001). This requires eighteen new and redevelopment projects, including the recently discovered Azadegan oil field, which contains 4 billion barrel of proven reserves.

About 30 percent of the oil produced in these oil projects is needed to pay the oil companies for the production cost via the earlier mentioned buyback contracts. So this share times the price of oil results in the dollar value of the buyback contract (BE); also see Eq. (6.11).

The total oil available from these development projects to fill Iran's OPEC quota is limited. The best guess by oil experts is that 55,000 to 65,000 barrels per day can annually be added to Iran's production capacity. It is assumed that the production capacity will be increased by 55,000 bbl/d per year for the period of 2002 to 2020, and that this new capacity remains available until the end of the period. As a result, the addition to the oil production capacity will reach 1.045 million barrel per day till 2020. The total capacity (old plus new development) will be 3.35 million barrel per day in 2020. Figure 6-27 shows the trends in existing oil production capacity and new investments.

Table 6-5. Exogenous variables assumption overview

Variable		Value in 1999	Unit
POP	1.5%	64,320,209	Head
NHOUS	2.0%	13,370,266	Household
NRHOUS	1.1%	4,667,042	Household
PLPG	10%	135	Rial/liter
PGSLN	10%	385	Rial/liter
PKER	10%	110	Rial/liter
PGSOIL	10%	110	Rial/liter
PFOIL	10%	55	Rial/liter
PNG	10%	54	Rila/CM
PELEC	10%	85	Rial/kWh
LIQUID	15%	225,803	Billion Rial
CAPIM$	5.0%	5.17	Billion US dollar
NOILR$	5.0%	3.63	Billion US dollar
FDI	2.0%	0.70	Billion US dollar
POIL	0.94%	22.0 1)	US$ per barrel
Oil production	55 bbl/d	0.0	1000 barrel per day
PASA	8.0%	7,176	Million passenger/KM
LOADA	5.0%	38,877	1000 tons/Km
NNGC	7.6%	3,752,105	Costumer

1) For POIL we used the actual price of oil for 1999 and started in the year 2000

The average growth rate of passenger/kilometer carried through the aviation system (PASA) was 6.1% per year within 1974-1998, but this is strongly affected by the war period. During the period 1988-1998 the average growth was only 4.4%. In recent years passenger transportation has, however, shown a slightly higher growth rate, 5.7% within 1995-1998. For the period till 2020 the growth rate for passenger transport is set at 5%.

The growth rate for cargo/kilometer (LOADA) was 5.1% over the sample period, but 8.9% for the period 1988-1998. Therefore, LOADA is assumed to increase by 8% per year until 2020.

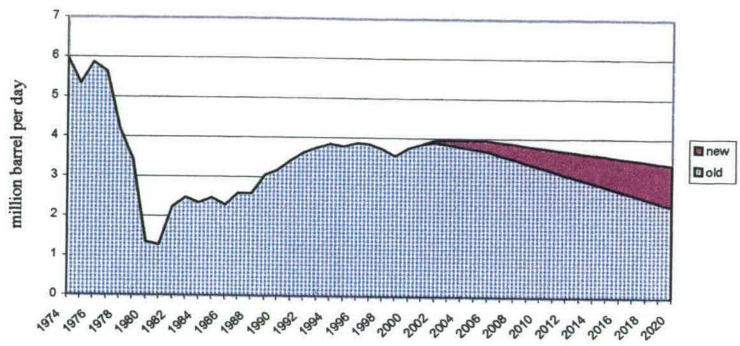

Figure 6-27. Iran's oil production capacity

The number of natural gas customers (NNGC), used as an indicator of natural gas market expansion, is affected mainly by the efforts of the energy authority to expand the infrastructure for the domestic market for natural gas. The Ministry of Petroleum and its subsidiary the NIOC execute the expansion policy. They are currently developing the greatest natural gas reserve in the world called "South PARS". The amount of gas available for Iran's domestic market is virtually unlimited. Also, the number of potential customers is no real restriction for the period until 2020. The growth rate of the number of natural gas customers was about 18.8% over the sample period 1974-1998, but has decreased in recent years to 7.6 percent. We assume that the growth rate of NNGC will on average remain 7.6 percent till the year 2020. This assumption seems reasonable, since more than half the country is not yet covered by the natural gas network.

6.4.2 Forecasting

Using the assumptions on exogenous variables of the previous section, we will now use the SE model to simulate the period 1999-2020. This simulation has been done using the package Eviews 4.0 for Windows, marketed by Quantitative Micro

Software. In this subsection we will discuss the results for the four sub-models and report on some other derived variables, such as energy intensity.

Macro Economic Variables

The growth in the overall economic performance decreases. Figure 6-28 shows the growth path of the main macro economic demand variables. The growth rates of some of the main demand categories are shown in Figure 6-29.

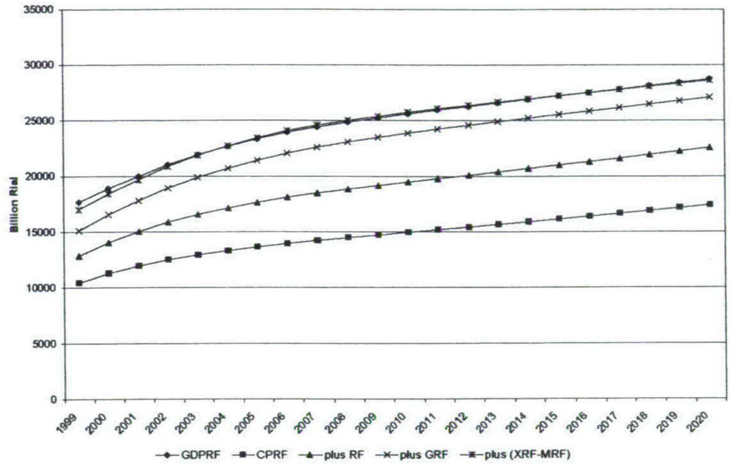

Figure 6-28. Main real macro economic variables

As Figure 6-29 shows, all macroeconomic demand categories show a strong increase at the start of the simulation period. This is the result of the strong increase in the price of oil in 1999 and 2000 (resulting in higher oil revenue), when oil prices recovered of the very low prices in 1998. After the year 2000 oil prices increase gradually, which explains the absence of hikes. Since we are interested in the long-term structural development and not in forecasting actual erratic behavior due to oil price dynamics, this is of no concern.

Because growth in real domestic energy prices is negative, domestic energy demand will increase faster than GDP, resulting in a decrease in oil available for export and thus the dollar inflow. Since the government depends the most on R$ for its expenditures, this demand category suffers most as is shown in Figure 6-29. At the end of the simulation period the growth rate is even slightly below zero.

If we compare the actual growth rate of the GDP for the period 1999-2020 with the growth rate over the sample period 1974-1998, these two are rather close, 2.4% and 2.2% respectively. The other variables also show only moderate differences, although on average government expenditure (G) grows a bit faster in the reference scenario due to the high long-term elasticity with respect to R$, whereas the average growth rate of private consumption (CP) is going down.

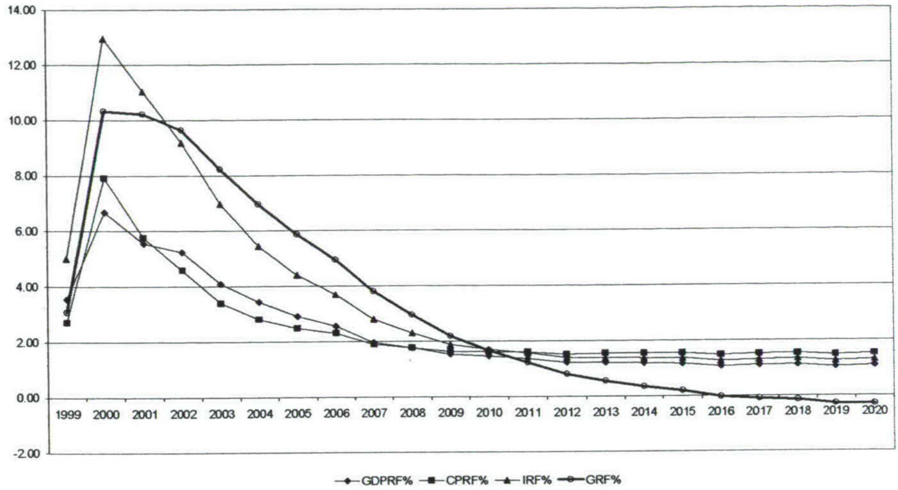

Figure 6-29. Growth rates of some macro demand categories

Two other variables are of interest, CPI and ER. As was shown in Chapter 3 these variables grew very fast, 20.6% and 23.0% respectively, over the sample period, especially in recent years, which was due to the high growth rate in liquidity (almost 25% annually). In the reference or RF scenario these growth rates are smaller due to our assumption on liquidity growth (15% annually). The growth rates of CPI and ER are of the same magnitude, 14.4% and 13.1% respectively. Note that the real price of energy is decreasing over the sample period as well as over the simulation period on average by almost 5% annually.

From this analysis we conclude that the results of our macroeconomic model, although it is only a partial model of the economy, can be used as a reference for the domestic energy policy analysis we want to perform.

Final Energy Demand

The growth rate of final energy demand (TFEDB) is on average 4.5% per year, whereas the domestic demand for oil (DOILD) increases on average by only 2.3% per year. This is mainly due to growth in the demand for natural gas; see Figure 6-30, which is the result of the gas for oil substitution policy. For the sample period these figures are 7.6% and 6% respectively. This indicates that the growth in energy demand is slowing down.

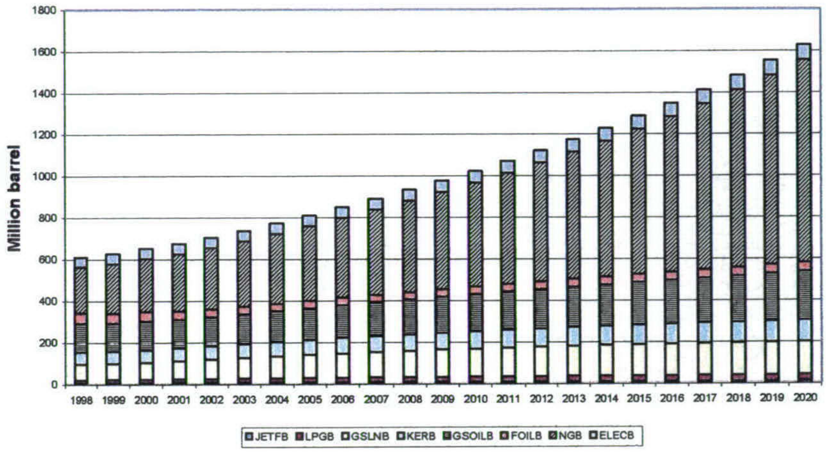

Figure 6-30. Simulated final energy demand in million barrels

In terms of barrel per day, the final demand for oil (DOILD) increases from 1.21 million barrel per day to 2.02 million. The total final energy demand (TFEDB) increases from 1.71 to 4.50 million barrels per day.

The growth in energy use, mainly by the non-productive demand categories as explained in Chapter 2, results in a constant increase in energy intensity based on final energy demand, since the growth in real GDP is only 2.4% per year compared to 4.5% in TFEDB. The oil product intensity is, however, almost constant, since DOILD grows by 2.3% only; also see Figure 6-30.

Figure 6-31 shows the shares of the different petroleum products in the total. The main changes are the decrease in the share of fuel oil (FOILB) and the increase in the share of gasoline (GSOIL). These developments are similar to the developments over the sample period. All other shares are almost constant.

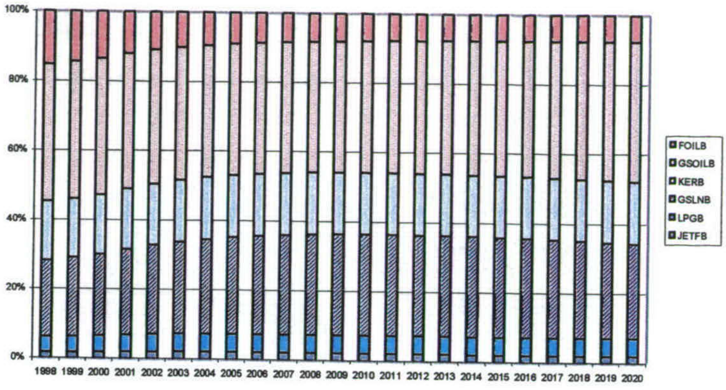

Figure 6-31. Shares of petroleum products in total petroleum product demand

Primary Energy Demand

Growth in total primary energy demand -power generation and refining- depends on the growth in final energy demand. As was the case for final energy demand, natural gas demand as a share of primary energy demand shows a strong increase; from 68% in 1999 to 76% in 2000.

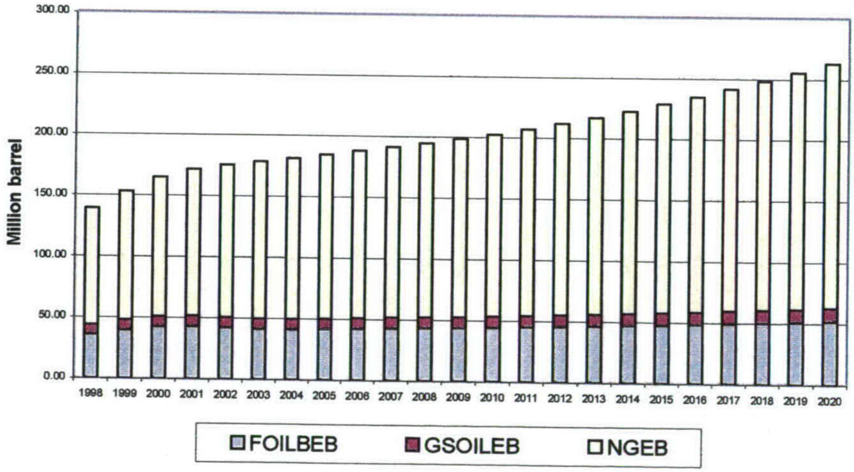

Figure 6-32. Primary energy use in the power sector

This is especially true for the power sector; see Figure 6-32. The total demand for energy by the power sector increases from 153.4 million boe per day to 263.1 boe.

Figure 6-33 shows the total primary energy demand (TPED), and two of its main contributors, the demand for natural gas in barrel oil equivalent (NGTB) and domestic oil demand (DOILD). Figure 6-33 also contains the annual oil production (QOIL/y) and the difference between QOIL/y and DOILD, which is the annual amount of oil available for export (XOIL/y). It is obvious that this amount is constantly decreasing. As a result the amount of oil revenue is decreasing also from 20.1 billion US$ in 2000 to 12.9 billion in 2020.

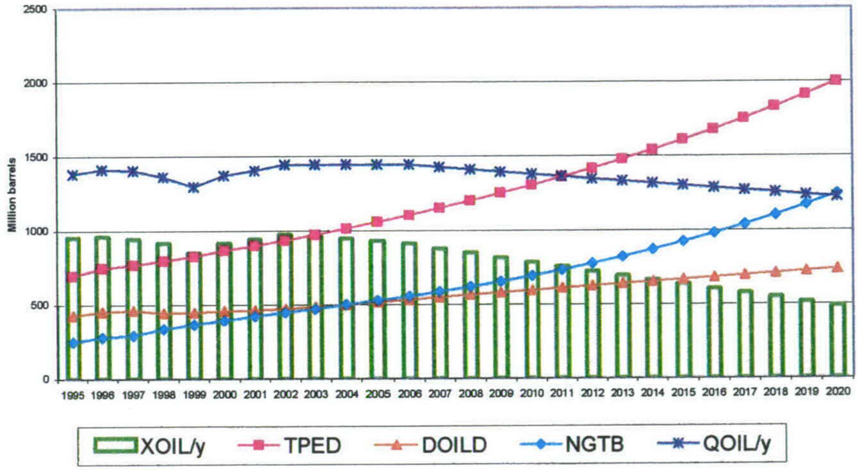

Figure 6-33. Primary energy use versus production

For those that are more familiar with barrels per day reasoning we provide the following. TPED increases from 2.18 million barrels per day to 5.48 and natural gas consumption in barrels (NGTB) more than triples from 0.92 to 3.35 million barrels per day. Because production (QOIL) is going down from 3.73 million barrels per day to 3.35 million and domestic demand in barrels per day (DOILD/365), despite the success of the gas for oil policy, is still going up from 1.21 million barrels per day to 2.02 million, the export is decreasing from 2.52 million barrels per day to a meager 1.33 million.

Next the results of the subsidy sub-model are briefly discussed.

Implicit Subsidies

The implicit subsidies on final demand for fuels under the reference scenario keep growing and reach a staggering 34 billion US$ in 2020; see Figure 6-34. The subsidies on fuels used in electricity production and refining are neglected, because the prices paid by these sectors -which are owned by and part of the government- are not known.

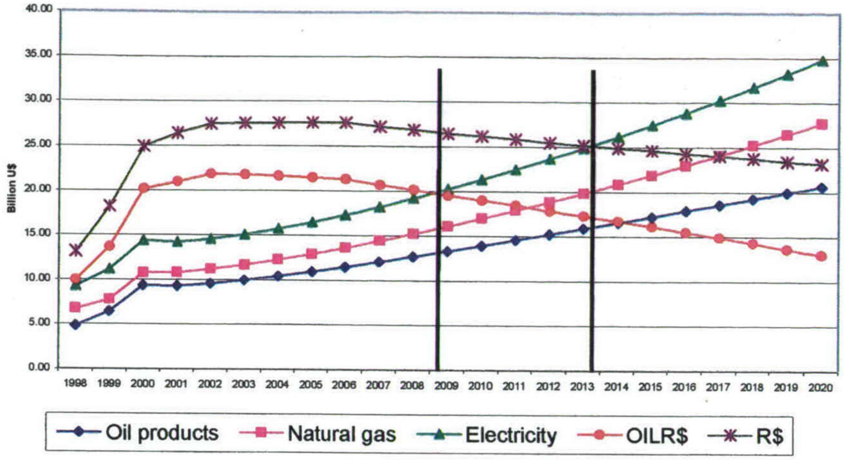

Figure 6-34. Total subsidies and its main components

With the final demand for electricity and for natural gas growing faster than the demand for petroleum products, the share of implicit subsidies on these fuels is increasing; see Figure 6-34. The fast growth in subsidies in the years 1999 and 2000 has to do with the extremely low oil prices in 1998 and the recovery of this price thereafter.

The figure also contains the income from oil export (OILR$) and the total dollar inflow (R$). As is indicated by two solid lines, the total amount of implicit subsidies will become larger than the total oil revenues by 2008, and by 2014 they will be larger than the total dollar inflow (R$). Although implicit subsidies are not actually paid, it is obvious that they are a strain on all government policy (and domestic energy policy in particular), and will seriously hamper all efforts to improve the health of the Iranian economy.

Finally, we add figure that shows the shares the different petroleum products have in the subsidies on final demand for petroleum products. This total increases from 9.35 billion US$ in the year 2000 to 20.6 billion in 2020. Between 2000 and 2020 the share of gasoline increases from 21.7% to 27.2%, whereas that of fuel oil decreases from 9.4% to 4.8%. The other shares are rather constant.

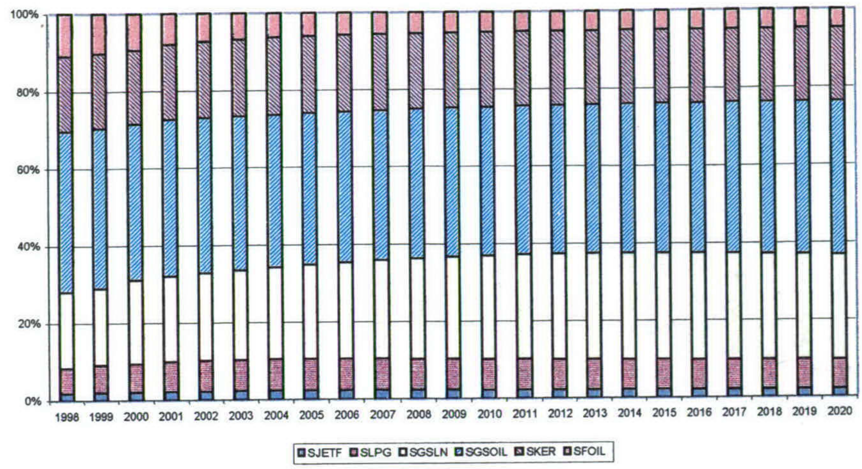

Figure 6-34. The shares of subsidies on petroleum products in the total subsidy on these products

6.5 Conclusions

In this chapter, the general model developed in Chapter 5 was specified and estimated. Although the Iranian data are of poor quality -in the model this has lead to separate equations for GDP and GDE-, the equations obtained are robust and show good performance, individually as well as a simultaneous equation system.

Next the model output for the sample period was used to compare the actual data per endogenous variable with the actual data using the correlation coefficient, Theil's inequality coefficient, and the ratios of the mean and the standard deviation. From this analysis it was concluded that the in sample simulation of the model performs well.

A reference or business as usual scenario was developed against which the new pricing policy introduced in the next chapter can be evaluated. For this scenario assumptions had to be made with respect to the values of the exogenous variables. These assumptions were based on sample behavior and known policy intentions. For example, the increase in the domestic energy prices was restricted, as was the increase in liquidity. We are aware of the fact that the model developed is only a partial model of the economy and that the Lucas critique is ignored. However, we believe that the links between our model and the assumption that energy prices and liquidity are exogenous variables do not affect our results too much. The model covers the main links between Iran's dollar income and macro economic demand. As was argued in Chapter 5, a more complete and concise investigation of the links between Iran's monetary sector and the domestic energy policy is beyond the scope of this research.

Analysis of the reference scenario shows that in spite of a low level of real economic growth, the high growth rate of the population and development of urban areas, in combination with sustained decreases in real energy prices, result in a strong growth in final and primary energy demand. This implies a further increase of the overall energy intensity.

The increase in energy demand is mainly met by natural gas, which almost triples. The model clearly shows the effect of the gas for oil substitution policy. In spite of the substitution policy the domestic demand for petroleum products, and thus oil, still increases from 1.21 million barrels per day to 2.02 million. Since many of the oil fields are past their peak production and the capacity from new developments that can be added is restricted (55,000 barrel per day per year), production decreases slightly from 3.73 million barrel per day to 3.35 million. As a result, oil export is decreasing from 2.52 million barrels per day to a meager 1.33 million, leading to a decrease in export earnings from 20.1 billion US$ in 2000 to 12.9 billion in 2020.

The implicit subsidies on final energy demand on the other hand show steady growth rates. The total amount by 2020 is a staggering 34 billion US$, compared to 14.4 billion in the year 2000. This figure includes subsidies on natural gas and electricity. For petroleum products these figures are US$ 9.35 billion and US$ 20.6 billion respectively.

In the next chapter we analyze the effect of removing the implicit subsidies and calculate the total potential for energy savings.

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Chapter 7
Optimizing Domestic Energy Demand

7.1 Introduction

This chapter discusses Iran's opportunities for energy conservation, which is one of three main policies resulting from the SWOT analysis in Chapter 4. The first policy investigated is removing the implicit energy subsidies, and how this affects energy demand and the main macro economic variables. The analysis is performed within the framework of the model developed in Chapter 6. The same assumptions on exogenous variables as for the reference scenario (further indicated as RF scenario) are used, with the exception for the domestic energy prices. The latter will, over a period of five-year period (2001-2006), be raised to the level of their respective border prices. This scenario is called the removing subsidy scenario (further indicated as RS scenario). After the year 2006 the real energy prices are based on the development in CPI and the increase in the international oil prices. The difference between energy demand in the RF and RS scenarios is interpreted as the amount of conservation from the upward adjustments of energy prices.

The results of this new pricing policy are discussed for the two periods 2002-2007 and 2007-2020 separately. The main reason for this is that during the first period domestic prices will be affected by the large energy price increases and we want to know how this affects the economy and inflation. (Most Iranians fear lower economic growth and higher inflation.) The second period is one of moderate price increases, but hopefully better economic performance. This also needs to be analyzed and compared to the reference scenario. It might be that positive effects of the new pricing policy during the second period offset possible negative effects of the price increases during the first period. The evaluation of pricing policy should be based on the effects of the policy over the whole period. The discussion will concentrate on aggregate variables, such as, primary and final energy demand, energy conservation, real energy prices, energy intensity, oil revenue, oil for export, GDP, CPI, and the exchange rate.

Although the energy prices are set equal to the border prices, Iran's energy prices in the RS scenario will still be among the lowest energy prices in the world, even when we compare them to current energy prices in other countries. In other countries domestic energy use is a major revenue raiser for the government, which is certainly not true for Iran, even after the price increases. This price comparison suggests that there is more room for energy price increases to conserve energy. However, with the Lucas critique in mind, analyzing such an additional long-term pricing policy with the model of Chapter 6 seems asking too much. The price increases will certainly change the attitude of consumers, which needs to be analyzed before the effects can be quantified.

To quantify the energy conservation potential for Iran, which can be achieved by higher energy prices and/or other conservation policies and measures, the conservation potential in some other countries along with their energy policies are analyzed next. This is a difficult task, because of the differences in economic structure and level of development between countries. However, despite these differences, such a comparative analysis makes sense if used with care.

The price and non-price energy conservation policies of the United Kingdom, the Netherlands, and Thailand are reviewed. These three countries were used because extensive information was readily available. Iran's energy conservation potential on top of the pricing policy will be based on this comparative analysis. However, where possible this will be complemented with available information on Iran's conservation potential. The capacity for energy conservation trough additional policy measures, so in excess of the pricing policy, will be estimated and it is assumed this will be effective within the period 2008-2020. This scenario is labeled as the Improved Scenario and is denoted as IM.

Since the conservation potential on top of the pricing policy is determined exogenously, the effects of conservation on macro economic variables cannot be analyzed. However, the effects on oil revenue and the energy sector, i.e. electricity system and oil refinery, are discussed.

Finally, in order to investigate whether our assumptions are realistic, the trend in the energy intensity in the IM case is compared to the prospects of energy intensities in other countries.

This chapter is organized as follows. Section 7.2 introduces the RS scenario for the period 2002-2007 and 2007-2020 respectively, and discusses the overall effect of the new pricing policy for the period 2007-2020. Section 7.3 compares Iran's increased energy prices in 2020 to the current prices in other countries. In Section 7.4 the energy conservation policies in the United Kingdom, The Netherlands, and Thailand are discussed. In Section 7.5 the conservation potential for Iran. In Section 7.6 this additional conservation potential is quantified. Section 7.7 presents the conclusions.

7.2 Removing Energy Subsidies

The RF scenario of the previous chapter shows that the amount of oil available for export is squeezed between a slightly decreasing production capacity and strong increases in the domestic demand for oil, to a meager 1.3 million barrel per day by 2020. The result is a steadily decreasing inflow of foreign currency, which in turn threatens Iran's development potential and the welfare of its people. This loss of market, in combination with high inflation could lead to similar problems as Argentina is currently facing, a complete loss of confidence internationally as well as domestically.

To avoid this the first policy action should be the removal of the implicit energy subsidies over a short period of time. Removing the implicit subsidies will improve Iran's energy efficiency and provide the government with financial funds to adjust its current monetary policy. This can be achieved by using the extra income from domestic energy sales to lower the growth rate of liquidity. As we shall show this will substantially lower the increase in the consumer price index. Part of the extra income can also be used to compensate the poor, who suffer most from the energy price increases. We will, however, not develop a scheme for this.

Note that real income in Iran is currently decreasing, because wage increases are lower than the rate of inflation.

In the RS scenario the implicit energy subsidies will be removed over a five-year period, from 2002 to 2006. To achieve this prices are increased by a fixed percentage every year during this period. These annual price increases for the various fuels in US$ per unit are:

PJETF	PLPG	PGSLN	PKER	PGSOIL	PFOIL	PNG	PELEC
62.4%	59.0%	27.3%	61.2%	60.4%	53.7%	40.8%	33.1%

After 2006, the energy prices will be set equal to the border prices, which are exogenous in our model. This is the Removing Subsidy or RS scenario. All other assumptions on exogenous variables, with the exception of LIQUID, are the same as in the RF scenario; see Sub-section 6.4.1.

In Sub-sections 7.2.1 and 7.2.2 the effects of the new energy pricing policy are evaluated for 2002-2007 and 2007-2020 respectively. In the first five years of the forecast period, the energy subsidies are partially abolished. In the second period the prices are set at their expected border prices to gurantee zero implicit energy subsidies. In Sub-section 7.2.3 the total period is briefly discussed and some conclusions are drawn.

7.2.1 Removing the Implicit Subsidies (2001-2007)

All macroeconomic and energy variables are affected by the policy to remove the implicit energy subsidies. In the following the effect the new pricing policy has on the main economic and energy variables is discussed.

Real gross domestic product (GDP)

In Iran many people are convinced that an increase in energy prices will reduce economic growth. However, in the long run a better economic performance can be expected, indicated by the rate of growth of GDP, when the implicit energy subsidies are removed. Economic agents improve their energy consumption, freeing oil for export. This in turn increases the dollar inflow R$. Since investment, consumption, and government expenditure are directly and indirectly affected by R$ this is expected to lead to a higher GDP. In the RS scenario, GDP is predicted to grow on average 3.9% annually within 2002-2007, which is an increase of one percent compared to the RF scenario; see Figure 7-1. So removing the implicit subsidies results in higher annual GDP growth rates, instead of lower economic growth.

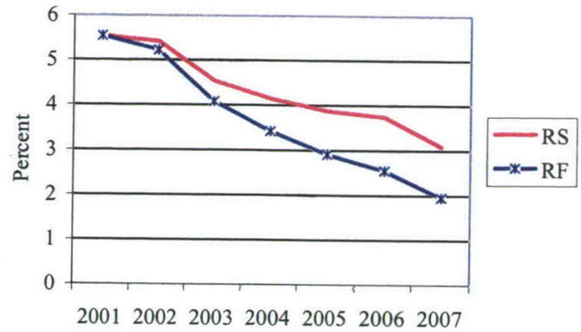


Figure 7-1. Forecasts of GDP growth in the two scenarios

Consumer price index (CPI)

Inflation is a critical macroeconomic variable. Many in Iran expect that drastic energy price increases, as the ones proposed here, will increase the already high rate of inflation even further. Removing the implicit energy subsidies increases the costs of supplying goods and services, especially the energy goods in the household expenditures basket. This would be true, if no other measures were taken.

Eq. (6.12) is not completely adequate for the analysis of the RS scenario. Strong energy price increases will, as expected, affect CPI, but this is not made explicit in our model. To account for this a study by the World Bank (2000) is used. This study estimates the share of energy expenditures in the budget of the average Iranian household at 0.018, which indicates the direct effect of energy prices on CPI. For the period 2002-2006, we include this percentage in Eq. (6.12), which becomes

$$LOG(CPI) = 5.179 + 0.018LOG(PENG) + 1.149\,(LOG(LIQUID)-LOG(GDPM82)) + [AR(1)=0.235] \qquad (6.12a)$$

The dynamic effect of the increase is accounted for by the AR term. For the analysis of the period 2007-2020, when energy price increases are small, we again use Equation (6.12).

Because the government receives a large amount in cash when the policy is implemented, some further adjustment of the model is required. The extra income (which in the end amounts to over 10% of the GDP; see Chapter 3) can be used for many things. An obvious one is the reduction in liquidity growth, since the government is no longer strapped for cash. In the RF scenario liquidity was assumed to grow at 15% per year. In the RS scenario we replace this by an equation. We assume that the government uses 50% of the extra income to reduce liquidity growth.

$$\mathrm{LIQUID}_t = 1.15\ \mathrm{LIQUID}_{t-1} - 0.5\ \mathrm{ER}_t^{RS}(\mathrm{SUBSID}_t^{RF} - \mathrm{SUBSID}_t^{RS}) \qquad (7.1)$$

LIQUID is defined as before, ER^{RS} is the free market exchange rate in the RS scenario, and SUBSID^{RF} and SUBSID^{RS} stand for energy subsidies in the RF and the RS scenario respectively.

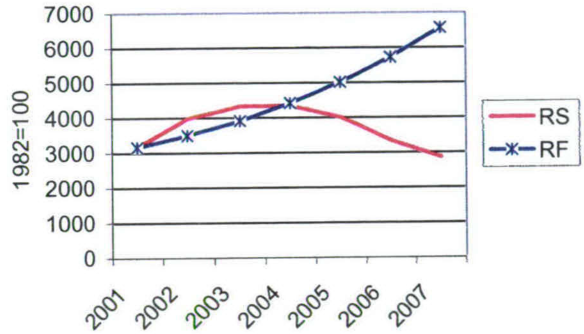


Figure 7-2. CPI trends in the two scenarios

become available after removing the implicit energy subsidies. As a result, the rampant inflation can be controlled instead of increased. In RS scenario CPI grows at about 1.08 percent annually against 11.9 percent in the RF scenario, an improvement of more than 10 percent. As figure 7-2 shows how the RS scenario outperforms the RF scenario after 2004. In the reasoning about removing the implicit subsidies, it is the link between the extra funds for the government and how these are used that most people forget. If used properly, their positive effect will more than compensate the negative effect of higher energy prices.

A second important issue when discussing removal of the implicit subsidies is the effect this would have on poor people. Although not in absolute terms, these would suffer the most. This problem should be addressed also. Although not part of this investigation, we are convinced that the extra income for the government is more than sufficient to compensate the poor.

Real price of energy (PENG/CPI)

The average real price of energy has decreased during the last decades, which led to a high domestic consumption of energy; see Chapter 2. In the RF scenario the average real energy price is decreasing, in line with its historical trend. In the RS scenario the adjustment of energy prices to the border prices, in combination with the lower inflation rate, results in an increasing trend for the real price of energy. As Figure 7-3 shows, the real price of energy in the RS scenario is expected to increase sharply; on average 32.7 percent per year.

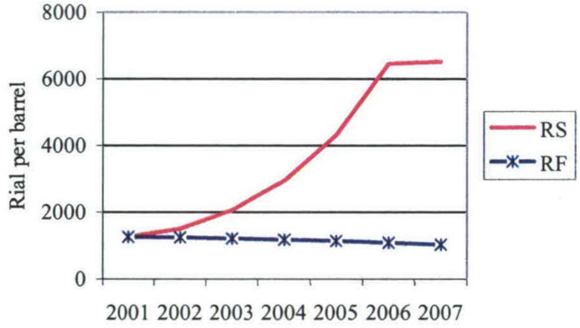


Figure 7-3. Average real energy price (PENG/CPI)

Oil revenue (OILR$)

As was shown in Chapter 2, the Iranian economy strongly depends on the oil dollar revenue. Historically, the revenue has fluctuated with the international price of oil and to a much lesser extend the amount of oil exported, although the latter shows a decreasing trend due to the strongly increasing trend in domestic oil demand. The increase in domestic oil consumption cannot be compensated by an increase in oil production, sin

revenue in the RF scenario is decreasing; see Figure 7-4. The figure also shows that with an increase in real domestic energy prices, revenue strongly increases from about US$ 21 billion to over US$ 24 billion. As we shall show later this is due to a strong decrease in domestic oil consumption.

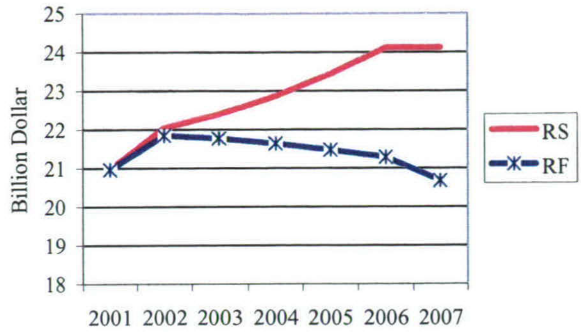


Figure 7-4. Oil dollar revenue (OILR$)

Exchange rate (ER)

In Chapter 6 we discussed the free market exchange rate, Eq. 6.42, as a function of the consumer price index (CPI) and the total dollar inflow (R$). The higher the CPI the lower the purchasing power of domestic currency and the higher the exchange rate is expected to be.

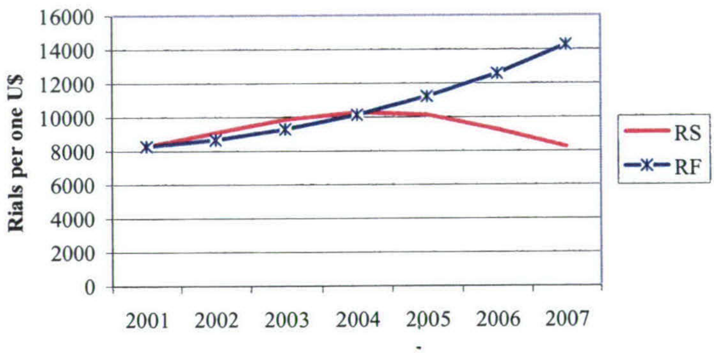


Figure 5-7. Rial-Dollar exchange rate (ER)

exchange market, the more the exchange rate is expected to appreciate. In the RF scenario the exchange rate deteriorates due to lower oil revenue and due to the high inflation rate, which is caused by the high growth rate of liquidity; both negatively affect the exchange rate. In the RS scenario these tendencies are reversed. The dollar inflow increases and due to the adjusted monetary policy CPI growth decreases drastically. As a result, the exchange rate slightly increases when the new pricing policy is introduced, but after the year 2004 the situation sharply improves and the exchange improves; see Figure 7-5.

Total primary energy demand (TPEDB)

Removing the implicit energy subsidies will result in lower domestic energy demand. In our model this is due to the own price elasticities, which represent the rationalizing behavior of consumers. Although energy is still a cheap commodity after the price increases, the use of more efficient technologies and better energy management become profitable. In the RS scenario, primary energy demand increases on average by only 1.2 percent annually, 3.1 percent less than in the RF scenario. Figure 7-6 shows that the annual growth rate of primary energy would be even slightly negative in 2006. In the RS scenario the growth rate is diminishing, while in the RF scenario it remains high at about 4 percent per year. The total primary energy demand (TPEDB) of 2.46 million barrel per day in 2001 will be 2.64 million barrel per day in 2007 in the RS scenario, against more than 3.1 million barrel per day in the RF scenario.

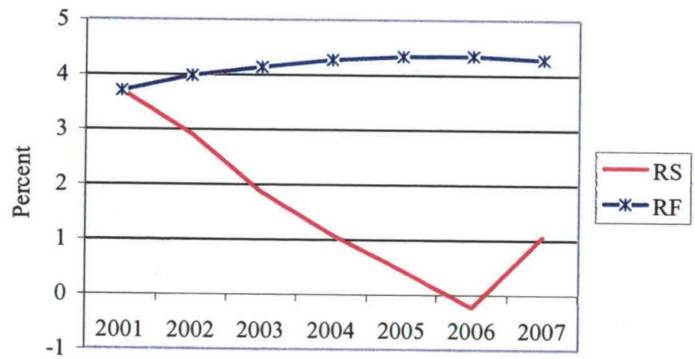


Figure 7-6. Primary energy demand (TPEDB)

The amount of oil in TPEDB is the most interesting component, since this directly affects R\$. In the RF scenario domestic oil demand (DOILD) is expected to increase by 2.83 percent per year, from 1.26 million barrel per day to 1.50 million; see Figure 7-7. In the RS scenario domestic oil demand decreases on average by 2.37

percent annually to reach 1.10 million barrel per day in 2007; a level equal to that of 1992.

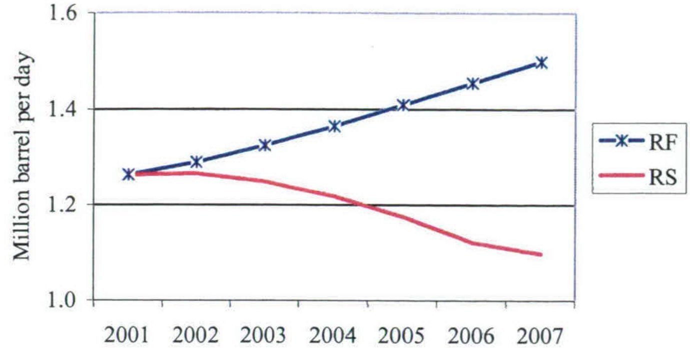


Figure 7-7. Domestic oil demand (DOILD)

Except for the solid fuels, which we kept exogenous, all energy carriers are affected by the new price policy. Since in our model the energy demand by the transformation sector is only indirectly affected by the price increases, we next

energy basket. Figure 7-8 depicts the ratio of energy demand in the RS scenario over the demand in the RF scenario. Except for jet fuel, the ratio is smaller than 1, indicating a lower demand in the RS scenario for all energy carriers. The opposite effect for jet fuel is the result of the higher GDP growth in the RS scenario. However, as was shown in Chapter 2, jet fuel is only a small fraction of total final energy demand.

Comparison of the average growth rates of each energy carrier shows that in the RS scenario all energies, with the exception of jet fuel, gasoline, and natural gas, show negative growth rates. The positive growth rate for gasoline in the RS scenario is mainly due to the higher GDP growth, resulting in a higher number of gasoline-using vehicles. Although the growth rate of this fuel is positive, it is still much less than in the RF scenario. Natural gas demand increases in both scenarios because of the continued gas for oil substitution policy, but the growth rate in gas demand in the RS scenario will be lower than in the RF scenario.

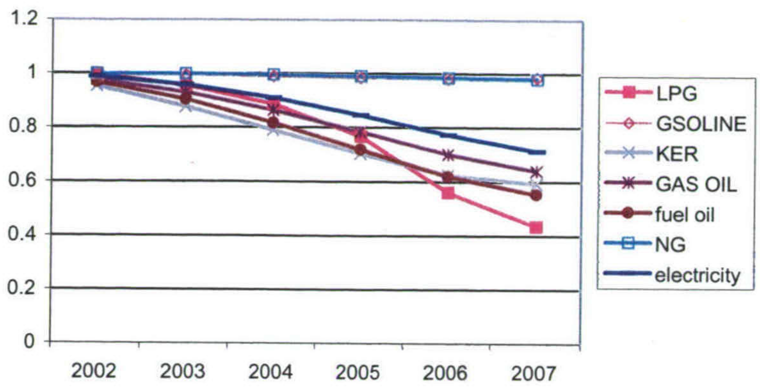


Figure 7-8. The ratio of final demand per carrier in the RS and RF scenario

Energy conservation

The purpose of removing the implicit energy subsidies is to increase foreign exchange income, to decrease the financial burden of the government -currently resulting in high liquidity growth-, and to promote energy conservation. Because of the price increases about 543.2 million barrel of oil equivalent will be conserved. The value of this amount of energy on the basis of the final energy prices, which are lower than the border prices within 2002-2006, is estimated at US$ 12.8 billion. The value based on the opportunity costs or border prices is US$ 13.02 billion.

This is the value of the energy conserved in the final demand sectors only. Lower demand for electricity, however, reduces the need for electricity generation and distribution, which in turn reduces the amount of energy needed in these two segments of the energy chain. The same holds true for the oil refineries, less demand for petroleum products leads to less demand for refinery and in turn reduces the losses. Therefore, the amount of energy conserved mentioned above is a lower bound rather than an upper bound.

Energy intensity

As is shown above, an effective and efficient domestic energy policy will reduce

From an economic theoretical point of view this makes sense since inefficient domestic energy use is replaced by extra dollar revenue, which boosts domestic spending. This is completely in contrast with what many Iranians fear, namely that energy price increases will lead to a reduction in economic growth.

The ratio of energy demand and GDP is known as energy intensity. The energy intensities for both scenarios are depicted in Figure 7-9, which shows two opposite trends. In the RS scenario the energy intensity is expected to decrease by 2.74 percent per year, while it is expected to grow by 0.90 percent per year in the RF scenario.

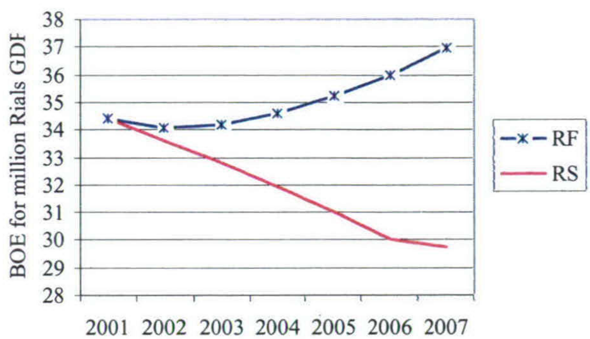


Figure 7-9. Final energy intensities

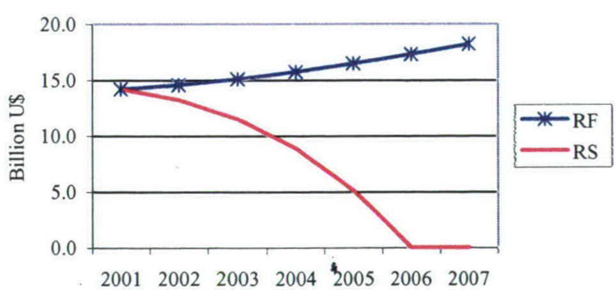


Figure 7.10. Removing subsidies

Energy subsidy

Along with the upward adjustment of energy prices towards the border prices, the implicit energy subsidies vanish; see Figure 7-10. The energy subsidies, which are about US$ 14.6 billion in 2002, are completely removed in 2006 and afterwards. The total implicit subsidies in the RS scenario would be US$ 38.7 billion; while in the RF scenario these amount to US$ 79.1 billion.

7.2.2 Energy Demand Under Border Prices (2007-2020)

Under the RS scenario the nominal domestic energy prices are set equal to the border prices, so implicit subsidies are removed for the whole period (2007-2020). To show that this is a rather modest pricing policy, we look at the real domestic energy prices. These do of course still change due to changes in CPI. Since the growth rate of CPI is larger than the increase in domestic energy prices, the real domestic energy prices will still show a slow decrease after 2006. This in turn will affect all of the above-mentioned variables. In what follows the effects of the new pricing policy are briefly discussed.

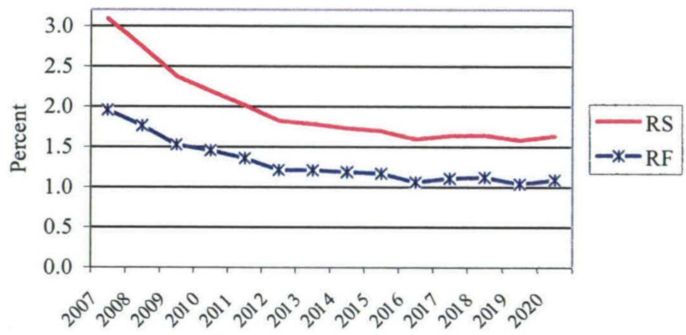


Figure 7-11. Annual growth rate of GDP in the two scenarios

Real gross domestic product (GDP)

In the RS scenario the real gross domestic product (GDP) is expected to grow faster than in the RF scenario within 2007-2020. The reason for this is the lower domestic oil demand, which results in higher oil revenue. The average growth rate of GDP is expected to be 1.87 percent annually, on average 0.63 percent higher than in the RF scenario; see Figure 7-11. Although the growth rates are decreasing in both scenarios, it stabilizes at a higher level (1.6%) in the RS scenario.

Consumer price index (CPI)

For the period 2007-2020 the growth rate of LIQUID is set at 5% per year. This assumption seems reasonable, since the government receives substantially more cash from domestic energy sales. Therefore, CPI is expected to be more stable in the RS scenario. The lower liquidity growth, due to a better monetary policy, stabilizes the CPI growth rate at about 3.8 percent. The ratio of CPI in the RS and the RF scenario (see Figure 7-12) shows a sharp decrease from about 43 percent in 2007 to about 10 percent in 2020. This reduction in inflation is one of the most important results of the improved energy pricing policy, since the extra income for the government that results from this policy can be used to curtail liquidity growth

Note, that this is only an indication of what is possible with adequate monetary

monetary policy is required to formulate precise policy measures. This is, however, beyond the scope of this research.

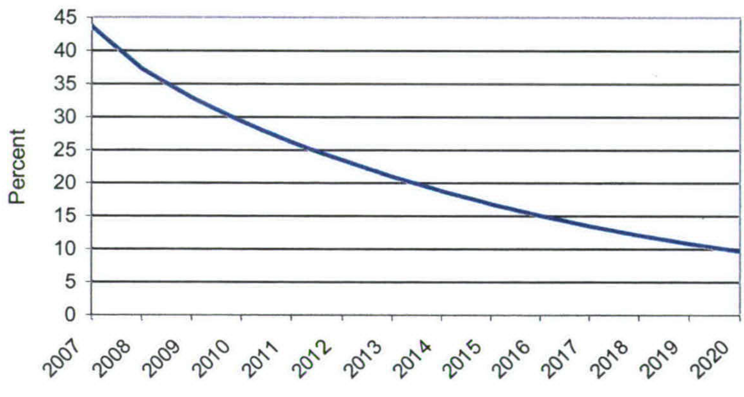


Figure 7-12. The ratio of CPI^{RS} over CPI^{RF}

Real energy prices

Because the growth rates of domestic prices of energy are lower than that of CPI, the real prices of energy are expected to decrease slowly within the period 2007-2020. It is expected that the real average price of energy (PENG/CPI) decreases 2.98% annually in the RS scenario, against 6.22% in the RF scenario, see Figure 7-13. This difference between the two real prices will result in a lower growth rate in energy demand in the RS scenario, leading to continued considerable energy savings.

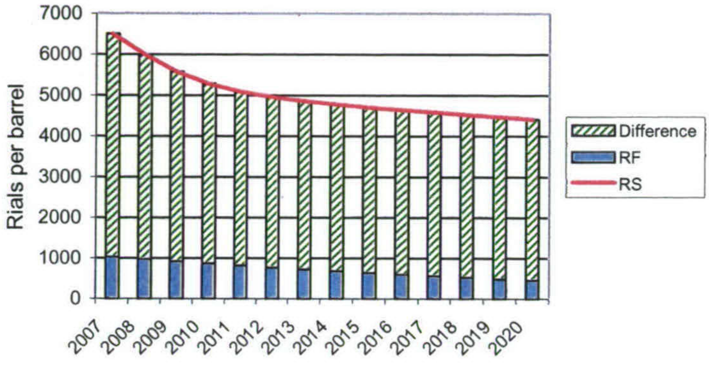


Figure 7-13. Real energy prices in the two scenarios

Oil revenues (OILR$)

The oil revenues in both scenarios are expected to decrease after the year 2006. But in the RS scenario the revenues are, of course, considerably higher than in the RF scenario; see Figure 7-14. The decrease in oil production is the main driving force for the decrease in the level of revenues in the RS scenario. The oil revenue in 2020 in the RS scenario is expected to be about US$ 20 billion, while it would be around US$ 13 billion in the RF scenario.

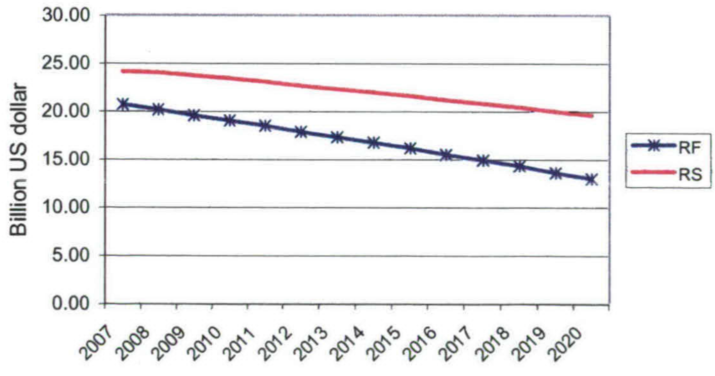


Figure 7-14. Oil revenue in both scenarios

Exchange rate (ER)

Because of the lower increase in liquidity (5 % per year instead of 15%) the value of

rio is much more constant than in the RF scenario. In the latter, the domestic currency is expected to lose more than 15 percent of its value annually. Because of the more stable economic situation in the RS scenario the Rial will be much stronger and loses only 1.4% of its value against the US$ annually; see Figure 7-15.

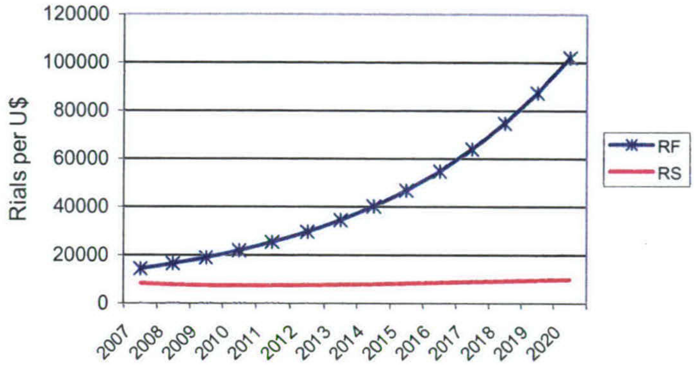


Figure 7-15. Rial-Dollar exchange rate

Energy demand

After the strong decrease in energy demand due to the removal of the implicit subsidies, total primary energy demand will start growing again. This is because of the decrease in real energy prices. The average growth rate of primary energy demand is estimated at 3.9% annually, about 0.33% lower than in the RF scenario. Primary energy demand will grow from 2.64 million barrel per day in 2007 to 4.39 million in 2020; which has to be compared to 5.48 million barrel per day in 2020 in the RF scenario; also see Figure 7-16.

Domestic oil demand will grow on average 1.5 percent each year and will reach 1.33 million barrel per day in 2020, which is close to the demand in 1998. The annual growth rate of domestic oil demand is expected to be 2.27 percent in the RF scenario, and demand would be 2.02 million barrel per day in 2020. Figure 7-17 shows the considerable differences between the two scenarios.

The demand for final energy carriers in the RS scenario is expected to be lower than that in the RF scenario. Although the real prices in the period 2007-2020 are not increasing, the effect of the price increases in the previous years does affect the demand for this period. Figure 7-18 contains the ratios of the demand for each carrier in the RS scenario over that in the RF scenario.

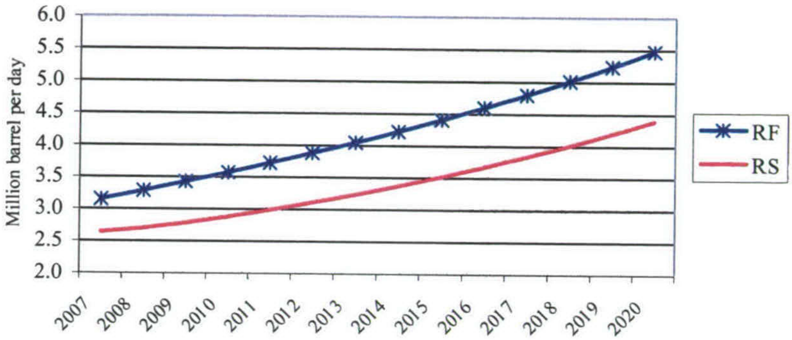


Figure 7-16. Total primary energy demand

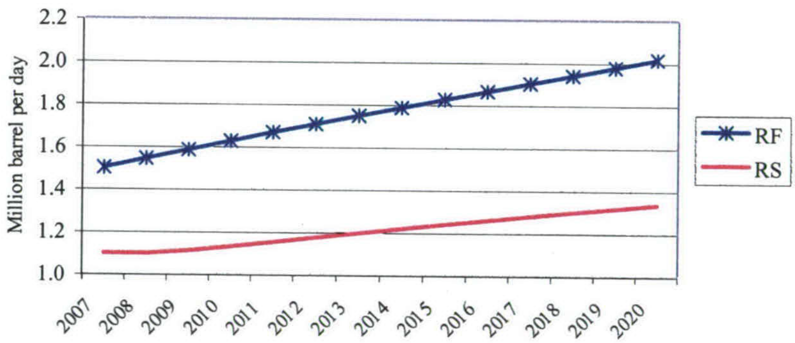


Figure 7-17. Oil demand

The demand for jet fuel in the simulated model is not affected by its price; therefore, we have excluded it from this comparison. It will keep on growing and will be about 20% larger in 2020 than it was in 2007.

Figure 7-18 shows that the demand for gasoline in the RS scenario is higher than that in the RF scenario. This is mainly due to the higher GDP growth under the RS scenario and its effect on the stock of gasoline-using vehicles.

The demand for natural gas in both scenarios is close to each other because the gas for oil policy continues.

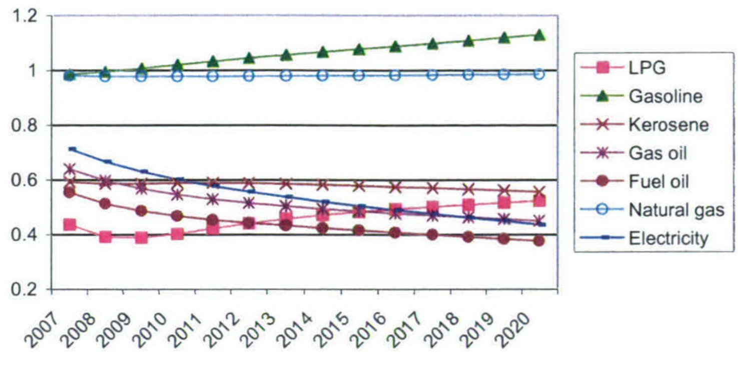


Figure 7-18. Ratio of demand per carrier in the RS and the RF scenario

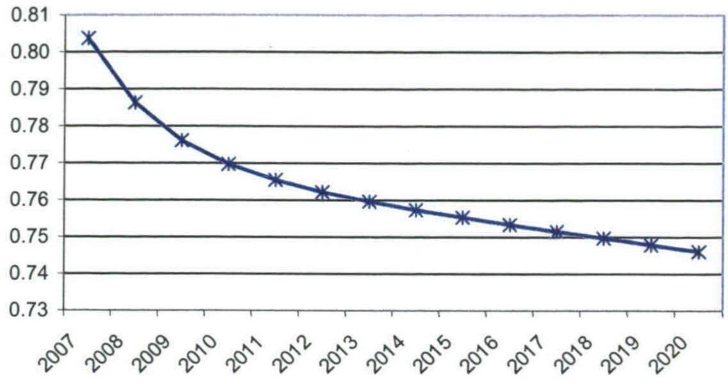
Energy conservation

Despite the fact that real energy prices decrease again compared to the period 2002-2006, the amount of energy conserved is still considerable; total energy conservation amounts to 4.2 billion BOE during this period. The value of this conservation is, given our assumptions on border prices, US$ 121.6 billion, which can be obtained by multiplying the differences in final energy use between the RF and the RS scenario by the respective border prices. Note that this amount is about 51 percent of the total oil revenues in the RF scenario.

Energy intensity

Energy intensity during the period 2007-2020 increases in both scenarios. The growth rate of energy intensity is expected to be 3.3 and 2.7 percent per year in the RF and RS scenario respectively.

Figure 7-19 shows the ratio of the energy intensities in the RS and the RF scenario. This ratio is diminishing indicating that under the RS scenario the economy is more energy efficient. The level of energy intensity in the RS scenario decreases mainly because of the higher real energy prices, which is partly offset by the better economic performance under this scenario. However, the slowly diminishing real



energy prices after 2007 in the RS scenario, lead to a slow increase of the energy intensity under this scenario also.

Figure 7-19. Ratio of energy intensities in the RS and RF scenario

Energy subsidy

Under the RS scenario the energy subsidies are completely removed for the period 2007-2020. The total amount of energy subsidies under the RF scenario is estimated to be more than US$ 379.9 billion or 1.6 times the total amount of oil revenues in the same period.

7.2.3 Overall Results Under the RS scenario

The RS scenario was discussed for two separate periods, 2002-2006 during which period the implicit subsidies are removed, and 2007-2020 during which domestic energy prices in dollar terms are kept at their border values. We showed that, even when energy price increases are high, the positive effects of the policy quickly overtake the negative effects of temporarily higher inflation. This requires, however, a monetary policy that is consistent with the new domestic energy pricing policy.

Table 7-1 contains the most important variables for the whole period, 2002-2020, which makes it possible to compare the overall results. The table shows that the

RS scenario outperforms the RF scenario on all reported variables. The annual GDP growth rate is 1.11 percent higher than under the RF scenario. The inflation rate (CPI) is, on average, low and quite stable in the RS scenario. The average real price of energy increases 6.0 percent per year in the RS scenario, while it decreases about 5.5 percent annually in the RF scenario. In the RS scenario the total revenue of oil export is expected to be US$ 423.3 billion or 1.26 times the revenues in the RF scenario.

Table 7-1. Overall performance of the economy in the two scenarios (2002-2020)

Variables	Value		Better performance	Description
	RS	RF		
GDP	2.44%	1.73%	RS	per year
CPI	0.37%	14.07%	RS	per year
Real energy price	6.00%	-5.54%	RS	per year
Oil revenues*	423.3 US$	335.0 US$	RS	billion
Exchange rate	0.44%	13.72%	RS	per year
Energy demand	3.07%	4.23%	RS	per year
Energy conservation*	4.56	-	RS	billion BOE
Energy intensity	1.32%	2.87%	RS	per year
Implicit energy subsidies*	38.7 US$	441.7 US$	RS	billion

* The amount for the period 2002-2020

The exchange rate is a very critical variable in the Iranian economy, and an unstable exchange rate results in instability of the whole economy due to its high dependence on export income. Iran's recent economic performance shows that the stability of exchange rate plays a key role in fostering economic growth and the promotion of non-oil export. The latter is vital for future diversification of Iran's economy. In the RS scenario the Rial loses on average only 0.44 percent of its value annually against the US$, while this would be 13.72% under the RF scenario.

The slowing down of energy demand growth under the RS scenario results in a large amount of energy conserved, amounting to 4.55 billion BOE. This is close to the proven oil reserves of countries such as Qatar, 3.7 billion bbl, Oman, 5.7 billion bbl, and the United Kingdom, 5.15 billion bbl (OPEC ASB, 2000). Total conservation comprises about 17.2% of total energy consumption in RF scenario. The ratio of the total primary energy demands in the RS and the RF scenario is given in Figure 7-20, which shows the sharp decrease when the implicit subsidies are removed, after which it stabilizes at about 80 percent. So after 2010 about 20 percent is saved annually.

The growth rate of the energy intensity under the RS scenario is expected to be 1.32%, 1.55% less than under the RF scenario.

The value of the implicit energy subsidies under the RS scenario is just 8.75% (or US$ 38 billion) of those under the RF scenario. The total value of the implicit subsidies under the latter scenario is more than US$ 441 billion US, which is a huge burden for Iranian economy.

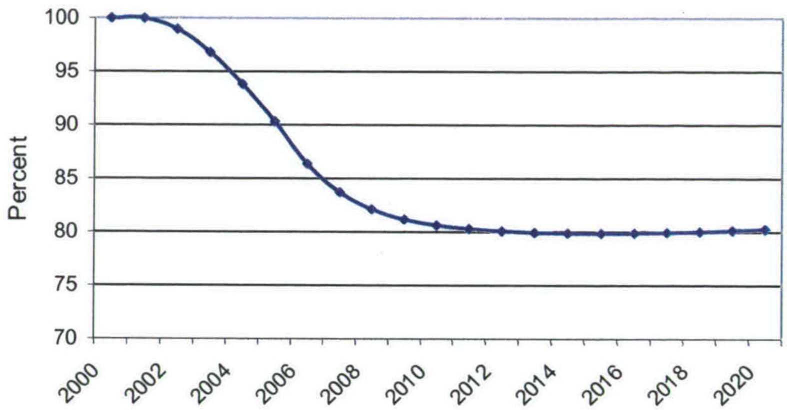


Figure 7-20. Ratio of total primary energy demand in the RS and the RF scenario

We have shown that a sound domestic energy policy not only can improve

f the

economy as a whole. The pricing policy in the RS scenario shows that all main economic and energy variables outperform those in the RF scenario. This is in strong contrast with public opinion in Iran, which states that removing the implicit energy subsidies will weaken the economy and lead to an even larger rate of inflation. As we have shown, if the new pricing policy is supported by sound monetary policy the overall performance will be better and the rate of inflation will after a short period strongly decrease instead of increase.

energy use. The next question that arises is whether removing the implicit subsidies is sufficient or can the pricing policy be enhanced by other policies (or even higher price increases)? These are the subjects of the next two sections. In Section 7.3

energy price in 2020 is compared with current prices in some other countries. The reason to do so is to show that even after the price increases Iran's energy prices are very low in comparison to other countries. In section 7.4 we analyze conservation policies in some other countries. These countries have conserved a considerable amount of energy using price *and* non-price policies. As we will see, even in the countries with the highest energy prices, there is still a considerable potential for energy conservation. This requires, however, additional conservation policies on top of the pricing policy. We want to use the potential in those countries to indicate (not estimate) that the conservation potential in Iran is much larger than the 4.55 billion barrel of oil equivalent obtained above.

7.3 Iran's High Energy Prices in an International Perspective

When asked, the average Iranian will regard the border prices for energy as introduced in the previous section as too high, unaffordable, and harmful to the economy. We have shown that this believe is a fallacy. Here we compare the Iranian price of energy in the RS scenario for 2020 with those in industrialized countries in the past to see how high the energy prices really are. For this we use the price of a composite barrel of petroleum products including taxes, which is considered a good indicator for the final price of energy; see Figure 7-21. The price range in the industrialized countries was between US$ 30 and US$ 76.5 per barrel in 1980, and between US$ 43 and US$ 142 in 1999. Over the total period the energy price of the UK belongs to the highest, whereas that of the U.S.A. belongs to the lowest. In this comparison Iran is neglected, because its price varied between US$ 2.5 and US$ 3.0 per barrel. However, as Figure 7-20 shows, even in the RS scenario the 2020 price of a composite barrel of petroleum products in Iran will be only US$ 36.20, far below the current prices in industrialized countries, and even below the current price in the United States.

The removal of the implicit subsidies leads to overall energy conservation of about 17 percent. Compared to energy savings in other countries this is still rather low. Most of the countries in Figure 7-21 have achieved higher energy savings. The main reason is that higher energy prices make energy saving investments profitable, and the fact that energy saving policies based on prices were supported by other policies. It is interesting to look at what other countries have achieved to see if this simulate these policies in our model, but we should be able to indicate the potential in combination with the policies used. Special emphasis will be on tighter regulation as support for the energy pricing policy.

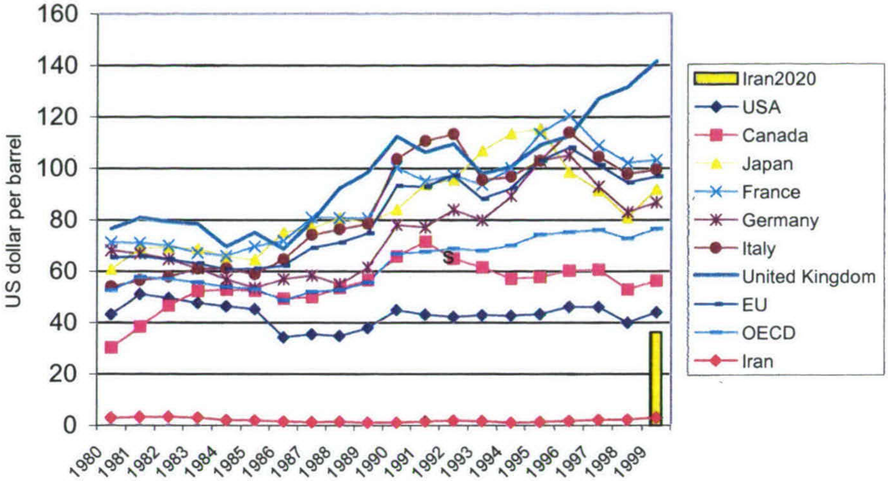


Figure 7-21. The price of a composite barrel of petroleum products

ings potential would be to estimate the technical-economical conservation potential in the different sectors of the economy by doing energy audits in firms, households, and offices using a stratified sampling technique and teams of experts. However, such a national research project is

conservation potential by using information from studies performed in other countries. Of course, such an estimate is highly unreliable, but it will indicate if research that is more detailed is required in the future.

The next section covers some studies for three different countries, the United Kingdom, the Netherlands, and Thailand, on energy conservation, based on detailed analysis of economic sectors. The studies typically use a year in the late nineties as a reference year to estimate the energy conservation potential. These potentials are, however, based on sustained high prices of energy; also see Figure 7-21. Since Iran has had sustained low energy prices, it is difficult to relate the conservation potentials to the Iranian situation. So we have to be cautious when estimating Iran's conservation potential. Luckily, also some sector studies for Iran are available.

7.4 Energy Conservation Policies in Various Countries

Section 7.2 showed that 17 percent of the energy consumed under the RF scenario can be conserved under the RS scenario by applying border prices only. Other countries have higher energy prices and a more comprehensive energy policy encompassing price incentives as well as regulations for energy use. If Iran would develop such a policy also, the amount of energy conserved could be substantially higher. In this section we will indicate how much more energy might be saved when a more comprehensive domestic energy policy is developed. Given our model, this can of course not be more than an indication or "guesstimate".

In the following the conservation potential and policies in three countries, the United Kingdom, the Netherlands, and Thailand are discussed. We choose these three countries because they have a good conservation record, and the policies are well documented.

The estimated potentials for energy saving in these countries require a balanced set of measures of price and non-price policies. As we will see, these policies have to be based on detailed knowledge of technologies and managerial issues, knowledge that is not (yet) available for Iran. The most important conservation instruments are institutional settings (energy efficiency agencies, etc.), building codes, labeling and standards, taxes and subsidies, energy audits, and economic incentives. It is also beyond the scope of this research to gather this information, which requires teams of domain experts and years of work. What we can do is identify the most promising options in other countries and try to link these to the Iranian situation. This will than be used to formulate a first guess of the potential savings for Iran on top of the 17 percent in the RS scenario. Of course, we can (and will) not identify the exact policy mix to achieve this, but we will give a short list of the most promising policy options.

It should be noted that for a country with an effective energy conservation program already in place for many years, and with a high level of domestic energy prices, the potential for energy saving will most likely be less than in a country at the early stage of energy conservation, and with low energy prices and almost no (enforced) regulation.

7.4.1 Establishing the Energy Savings Potential

Before we can discuss the energy savings potential of any country, it is necessary to define this concept. Different types of energy savings potential have been distinguished, ranging from technical to economic. Any discussion of this subject that does not explicitly define what is used is useless.

The Royal Commission on Energy Pollution (RCEP, 1998) distinguishes three types of energy savings potential, *technical*, *economic*, and *market*. The technical savings potential is the maximum possible energy saving by applying all possible measures as soon as they become available, regardless of the cost of the measures. The economic savings potential means that those measures are applied whose net benefits are positive. For this the RCEP uses discount rates ranging from 8% in the housing sector to 18% in industry. In this case many technically feasible conservation projects are not economically viable. Note that transaction costs are not taken into account and the energy efficiency gap is neglected (Van Soest and Bulte, 2001). The *market* or *likely savings potential* is the amount of economic potential that is expected to actually materialize in the various economic sectors under the current government policy. This potential shows the actual expected market penetration in the business as usual scenario. Note that the economic as well as the market savings potential are strongly affected by the discount rate used.

Others have made similar distinctions in savings potential. Jaffe et al. (1999) argue that when energy policies and regulations for conservation are discussed, a clear distinction should be made between economic efficiency and energy efficiency, since they are not the same and should be distinguished. The optimum level of energy efficiency based on technical criteria has in general a low economic efficiency. Economic efficiency and energy efficiency improvements require several steps. First, all market failures in the market of energy technologies have to be eliminated, next market failures in energy supply and demand, and environmental externalities need to be removed. This leads to the social optimum in the plane of energy efficiency and economic efficiency. If only those policies are taken into account that can actually be implemented, Jaffe et al. call it the "true social optimum". It is this true social optimum that should actually be looked for when establishing the energy savings potential.

Note that this is not the same as the RCEP's market savings potential, since that potential does not include policy changes, nor is it the RCEP's economic savings potential since that does not account for transaction costs.

The main reason why most studies use either the technical or the economic savings potential is that these are the simplest ones to establish. All other concepts require a more sophisticated analysis and more judgment. For this study this means that whatever potential savings we calculate, these will only be rough indications that can only be substantiated by more detailed studies.

7.4.2 Energy Saving Prospects in the UK

A study developed by the Royal Commission on Environmental Pollution's (RCEP, 1998), which was based on several other studies, has estimated energy conservation in domestic housing, services, industries, and the transport sector. For these estimates they used several detailed studies. In the following these estimated conservation potentials are reported per economic sector.

- **Housing sector**

Several technologies are available, such as, insulation of loft and walls, improved hot water supply and boilers, draught proofing and double-glazing, and the application of energy efficient appliances and lighting. In the various studies used the largest outstanding technical potential of energy savings are in solid and cavity wall insulation, and by using condensing boilers. The total technical conservation potential by all the measures mentioned is estimated to be between 25% and 34% of 1996 energy consumption.

The economic energy savings potential were by all sources estimated at about 15% in the short-term, rising to 30% over a period of 20 to 30 years.

The market potential is estimated to be just enough to offset the increase in demand due to a growing number of households and increasing use of electrical appliances and heating. So with no policy changes energy demand will effectively be stable.

- **Services Sector**

The service sector encompasses a wide variety of activities and the main sub-sectors are health, education, government, sports and entertainment, commercial offices, communication and transport, hotels and catering, retail, warehouses, and others. Energy use in this sector is mainly related to the buildings used, such as hospitals, schools, governmental offices, cinemas and theatres, railway stations, hotels and restaurants, retail- and department stores, warehouses and storage depots, community centers, and churches.

Twenty-five techniques have been modeled for estimating the energy savings potential. These cover heating, lighting, cooling/ventilation, office equipment, and the fabric of the building. The total technical savings potential is estimated at 39% of the total 1996's energy consumption. The economic and market potential energy savings for these measures are 24% and 11% respectively.

Note that combined heat and power applications as well as the effect of good housekeeping and energy management are not included in this savings potential. The latter can lead to considerable extra reductions.

- **Industry Sector**

Six major industrial sectors have a large potential for cost-effective energy savings. These industrial sectors are in order of energy used, engineering, metals, chemicals, paper and textiles, minerals and ceramics, and food and drinks. For these sectors it is important to distinguish between short-term, medium-term, and long-term measures. In the short term only existing equipment can be optimized; this includes boilers, motors, compressed air, refrigeration, and lightning and heating. In the medium term (3-10 years) improvements can be based on the application of combined heat and power (CHP), improved boilers and refrigeration systems, waste heat recovery, etc. All these measures are based on retrofitting and some additional equipment. The long-term measures are based on rethinking the processes used and investing in benchmark technology, such as direct reduction instead of blast furnaces in iron production and large CHP installations; see RECP (1998, 50-51).

The level of potential energy savings has been estimated for these industries under different scenarios for the years 2000, 2010, and 2020. For the combined sectors, the total technical savings potential is 29% in the sort-term, 36% in the medium-term, and 44% in the long-term. The economic potential for these three periods, based on a more realistic 15-25% discount rate (instead of 8%), is 15%, 23%, and 31% respectively.

The market potential is estimated at half the economic potential. The main reason for this difference is the earlier mentioned efficiency gap.

- **Transport Sector**

The transport sector in the UK, as in any other country, shows a steady increase in energy consumption, and its share in total energy consumption is expected to increase till 2020. For this sector three types of energy savings measures are distinguished: operational, strategic, and transport demand.

Operational energy saving measures can lead to immediate energy savings by adopting good operations and fuel management practices, including effective monitoring of fuel use, driver training, and providing incentive maintenance programs. In the freight sector energy savings of up to 20% can be achieved without much additional investments.

In the cars industry, reductions in energy intensity from 10% to 15% are predicted for the years of 2010-2020 based on a wide range of measures, such as lower car weights, lower rolling and air resistance, etc. Improved aerodynamic resistance of heavy vehicles and aircraft can bring about even larger energy savings of 20-30% per unit of transport.

The improvement in the energy intensity of petrol-engines is possible with the application of new and advanced engine technology. A reduction in energy consumption of about 15% to 30% is possible by packaging technologies, comprising lean burn combustion, varying valve timing, adding valves per cylinder, considering multi-point injection, and ratifying combustion engine with direct injection. Diesel engines are already very efficient in heavy vehicles and their potential energy savings is no more than 10-20% in the long term. An improvement of about 30 percent in fuel efficiency is expected in the aircraft industry by 2010.

Strategic measures will optimize the use of individual vehicles and the transport system, and complement the operational measures mentioned above. Improving travel routes and vehicle load factors are the main goals to be achieved.

Demand reduction can be achieved by land use planning and travel substitution. Land-use planning covers the places where people live and work, in combination with the places where goods and services are produced and sold. Travel substitution involves the provision of access to services without the need for traveling (tele-working, video-conferencing, etc.).

For this sector a technical energy saving potential of about 33 Mtoe in the medium term (2010) and 57 Mtoe in the long-term (2020) is estimated, compared to business as usual. This is about 38% and 111% of the 1996 transport consumption. The economic potential in 2020 will be about 36 MTOE, which is about 69% of 1996 energy consumption of transport sector. However, the economic potential in this sector can only be realized when policy adjustments are implemented. The market potential is much lower, so intervention is required.

Next, the main energy saving policies applied in the United Kingdom are discussed.

Table 7-2. Energy prices and taxes in the United Kingdom in 2000 in US$/liter

Fuel type	Price component	Tax component	End-user price	Tax as % of final price
Unleaded gasoline	0.296	0.913	1.209	75.5
Gas oil: commercial	0.314	0.730	1.044	69.9
Gas oil: non-commercial	0.315	0.915	1.23	74.4
Light fuel oil	0.263	0.062	0.325	19.2
Natural gas: residential*	278.7	14.1	292.8	4.8
Electricity: residential**	0.102	0.005	0.107	4.8

Source: IAE/OECD, Energy prices and taxes, 2001;
* dollar per 10^7 kilo Calorie; ** Dollar per kWh.

7.4.3 Energy Saving Policies in the UK

In the UK not only prices of energy contribute to energy conservation, but also many non-price policies promote energy saving. In the following, the main institutional and regulatory policies are addressed.

- **Prices and taxes**

End-user prices in the UK are high compared to many other countries and they are considerably higher than the international market prices. This is due to the high taxes and levies on energy consumption. For gasoline and gas oil in the non-commercial sector taxes contribute about 75 percent to the end-user prices; see Table 7-2 for an overview of energy prices. This high level of energy prices not only lead economic agents to demand energy services more rationally, they also induce them to invest in energy conservation options.

- **Energy efficiency agencies**

The focal attention of these institutions is on promoting energy efficiency. All EU countries have set up national, regional and/or local agencies.

- **National programs of energy efficiency**

The energy efficiency program is a national program that aims at 20% reduction in CO2 emissions by 2015, taking the 1990 level as starting point. The main contribution to this reduction has to come from energy savings.

- **Building codes**

Energy efficiency standards are defined in building codes and are mandatory in the UK for both residential and non-residential buildings. The European Commission has provided the latest building code directives to all member countries. The thermal building codes are mandatory and a building certificate is compulsory.

- **Labeling and efficiency standards for appliances**

These two policies are complementary. Mandatory labeling for most electrical appliances exits in all EU countries and is based on the same regulation in all countries. The regulations are based on EU directives and have replaced the existing regulations. Labeling of refrigerators, washing machines, and lamps, and of all cold and wet appliances is compulsory (WEC, 2001b, p 135). Also efficiency standards known as minimum energy performance standard (MEPS) are mandatory for some appliances in the EU countries. For refrigerators MEPS are mandatory, but for washing machines voluntary. Average electricity consumption of new appliances has been decreasing for 30 years in the UK from 710 kWh/y in 1975 to 645 kWh/y in 1995 (WEC, 2001b, p 136).

- **Fiscal measures**

Fiscal policies include taxes on car purchases, car ownership, fuel, road user charges, scrapping old cars, and the introduction of clean and efficient cars. Car purchase tax exists in the UK, although the amount of tax is very low compared to other European countries, especially Denmark. (The car purchase tax without the value added tax in Denmark is about US$ 16,000.)

In the UK consumers have to register their car every year and pay car ownership tax of more than US$ 150. Among the European countries, the UK tax is relatively low. There is no road pricing in the UK and highways are generally free of charge. It is estimated that the specific taxes paid over the lifetime of a car is US$ 11,840 (WEC, 2001a, p 85).

Income tax relief related to journeys to work is applied in the UK. In this country the tax relief is, however, limited either in terms of distance or by allowing it for public transport use only.

- **Subsidies and economic incentives**

A new institution, the Carbon Trust, has been set up in early 2001 and is responsibility for a program of energy efficiency support measures for businesses. New taxation measures support this institution. The climate change levy is a major new energy related tax, applied since April 2001. The levy is expected to raise 1 billion British Pounds in the first year. Investment enabling measures, including an enhanced capital allowance scheme, gives capital allowances of up to 100% in the first year for approved energy saving instruments in the corporation or income tax bill (WEC, 2001b, p164).

- **Policies on Cars**

A road tax exists in the UK, and before March 2001 it was € 147 for cars less than 1200 cc, and € 224 for cars over 1200 cc. This has been changed, and the tax is now based on the amount of CO_2 emitted. For petrol cars it is between € 140 and € 217, and between € 154 and 224 for diesel cars (WEC, 2001b, p 174).

- **Clean and efficient cars**

Subsidies and some economic incentives are considered to promote electric and CNG cars in the UK.

Next we discuss the Dutch energy policy.

7.4.4 Energy Saving Prospects in the Netherlands

Several energy conservation studies have been conducted for the Netherlands, with a national as well as a local scope, and for different time horizons. The method used was either bottom-up or top-down. In order to have a comparison of the potentials we reproduce the estimates of the studies as reported in "Integrated evaluation of energy conservation: national report for the Netherlands" (Uyterlinde et. al., 1999).

Table 7-3. Technical and techno-economic energy conservation potential as a percentage of energy demand for various sectors

	1990		2015
Sectors	Techno-economic Optimum	Technical Optimum	Technical Optimum
Industry	11.4	20.0	28.5
Agriculture	24.5	68.6	76.9
Dwellings	34.5	42.5	44.0
Services	28.1	38.0	59.9
Transport	10.0	17.1	28.2
Total	20.9	32.2	41.0

Source: Uyterlinde et. al., 1999, p 54.

TNO Study

The Netherlands Institute for Applied Research on Natural Sciences (TNO) has carried out a study entitled "TNO-Energy saving potentials 2015". This 1990 study calculated a technical and a techno-economic conservation potential for the year 1990 and a technical optimum for the year of 2015 using a bottom-up approach for twelve economic sectors. The techno-economic energy conservation potential is based on the profitability and the technical feasibility of presently available technologies, while the 2015 technical conservation potential is based on a 100% penetration of technically feasible options. So the latter will overestimate the conservation potential. The base year is 1986. The energy saving potential is reported in Table 7-3. The TNO study shows a pattern similar to the UK results discussed above, the techno-economic potential is between 35% and 81% of the technical feasibility.

ICARUS-3

The ICARUS-3 study was conducted by Utrecht University for the Dutch Ministry of Economic Affairs, had a national scope, and covered all economic sectors and energy carriers. It uses a bottom-up approach and considers a wide range of detailed technology options for energy conservation. Cost-effectiveness is considered sufficient to invest and analysis is at the level of economic sectors. The base year is 1990 and the sight years are the year 2000, which is based on currently commercially available techniques, and the year 2015, based on technology development assumptions and pre-specified price development assumptions.

Table 7-4 contains the conservation potential in each sector that can be achieved based on a combination of technical availability and cost-effectiveness. Since in the long-term improved technologies become available and market penetration is increasing, the conservation potential as a percentage of total consumption is increasing. The total conservation potential for 2000 was 30% of the primary energy, while it is estimated at 65% until 2015.

Table 7-4. Energy conservation potentials by economic sectors in the Netherlands [%]

	1990 – 2000			1990- 2015		
Sectors	Fuel	Power	Primary energy	Fuel	Power	Primary energy
Industry	26	20	24	38	26	35
Agriculture	47	44	46	75	57	73
Services	41	40	40	74	52	65
Households	42	40	41	76	35	64
Transport	17	19	17	45	37	45
Total	30	30	30	52	36	49

Source: Uyterlinde , 1999, p 44.

CENECA

The Dutch Central planning Bureau has developed the CENECA model. A macro-economic perspective is considered, and energy taxation is modeled to affect the national economy as whole. This study is a top-down analysis. The base year is 1990 and the sight years are 2000, 2005, 2010, and 2015. In this study the effects of energy taxes on energy conservation have been studied. The results with respect to energy conservation due to these taxes are in Table 7-5. Scenario A assumes a 50% increase of energy tax on prevailing energy prices of fossil fuels in the OECD area, while scenario B reflects a 50% tax increase in the Netherlands only.

What is surprising in the results of this study is the low savings potential of households in comparison to most other studies. This indicates that for this sector energy pricing measures (the only policy implemented in this study) need to be accompanied by other policies to achieve the full conservation potential.

Table 7-5. Energy saving by sectors as percentage of energy demand [%]

Sector / Fuel	Scenario A	Scenario B
Industry:		
Fuels	53.3	58.7
Electricity	28.8	32.8
Households:		
Fuels	2.4	5.7
Electricity	3.4	3.5

Source: Uyterlinde, 1999, p 58.

REDUCE model

The "Reduction of Energy Demand by Utilization of Conservation of Energy" or REDUCE model uses a bottom-up approach and takes into account all techno-economic aspects of energy conservation options (Uyterlinde et al., 1999). In this model the driving forces for energy conservation are cost-effectiveness, rates of return, payback periods, etc. The base year for the analysis is 1995, and two sectors, households and manufacturing, are analyzed. The forecasts of energy demand are reported in three scenarios, i.e. "energy use without saving", "actual baseline", and the "saving case". The actual baseline is the energy demand corrected for energy conservation reached by conservation equipment installed in the base year. Table 7-6 contains the energy saving in 2020 as a percentage of the actual baseline demand for household and manufacturing.

Table 7-6. Conservation potential in 2020 as a percent of baseline demand

Sector	Economical	Technical
Household	10-30	50
Manufacturing*	17	21

* Unaffected industries and non-energy use of energy demand is excluded.

Source: Uyterlinde et. al., 1999; based on the REDUCE model.

In REDUCE two types of energy savings are distinguished, technical and economic (based on a sufficient IRR). In 2020 in the household sector the energy savings potentials are for lighting 25% (technical 50%), for cooling 35% (technical 85%), for cooking 20% (technical 35%), for appliances 35% (technical 55%), for washing and drying 15% (technical 35%), and for hot water 25% (technical 50%) of the baseline energy demand in 2020.

For the Dutch manufacturing sector, a total of 153 technology options have been specified, of which 56 options are in the unprofitable range with an internal rate of return (IRR) of below 10% or even negative. Forty-eighth options have an IRR greater than or equal to 40%, and the rest is in between. However, energy tax policies as well as subsidies make a wider set of options economically viable.

The studies show different types of outcomes and different magnitudes of savings potential. All use rigorous energy modeling to obtain the results, but the decision criterion for a technology to become feasible may be too optimistic. The market potential perspective as used in the UK seems missing. What can be learned, however, is that energy-pricing policies alone are insufficient to achieve the full energy savings potential.

7.4.5 Energy Saving Policies in the Netherlands

In their attempts to protect the environment by conserving energy, the Dutch authorities apply a wide variety of policy instruments. These include prices, taxes, subsidies, and mandatory and voluntary agreements.

- **Fuel prices and taxes**

The prices of final energy in the Netherlands are very far from their border prices because of high taxes on fossil fuels. The price of gasoline for end-users in the Netherlands is, at more than 1US$ per liter, about 6 times the international spot market price. Table 7-7 shows the market prices and the shares of taxes in these prices.

The high prices of energy for end-users increases the profitability of conservation options. In the REDUCE model it was shown that an additional 8% of the reference energy consumption can be conserved in response to an average price increase of about 45% (Uyterlinde, et. al., 1999, p 123).

In the Netherlands there is also a green electricity policy in place. The users of green electricity, which is electricity produced from renewable energy sources, are exempted from some of the energy taxes, this to make them more competitive.

Table 7-7. Energy price and tax components in the Netherlands in US$/liter in 2000

Fuel type	Price component	Tax component	Final price	Tax as % of final price
Unleaded gasoline	0.362	0.708	1.070	66.2
Gas oil: commercial	0.341	0.324	0.665	48.7
Gas oil: non-commercial	0.385	0.497	0.882	56.3
Light fuel oil	0.309	0.210	0.519	40.5
Natural gas: residential*	232.5	126.9	359.4	35.3
Electricity: residential**	0.091	0.040	0.131	30.6
Electricity: industry**	0.055	0.002	0.057	3.8

Source: IAE/OECD, Energy prices and taxes, 2001.
* US$ per 10^7 kilo Calorie; ** US$ per kWh.

- **Energy efficiency agencies**

The focal attention of these institutions is on promoting energy efficiency. Most activities are coordinated by the Novem organization, an agent of the Dutch Ministry of Economic Affairs. Novem mainly works for the Dutch government (Ministry of Economic Affairs (EZ); Housing, Spatial Planning and the Environment (VROM); Transport, Public Works and Water Management (V&W) and Agriculture, Nature Management and Fisheries (LNV)), but also carries out a variety of international tasks for clients such as the International Energy Agency, the European Union, United Nations and the World Bank (http://www.novem.org/). Novem has four offices in the Netherlands (WEC, 2001a, p 55). Novem focuses on four specific themes (closely related to the ministries mentioned before), sustainable building, sustainable energy supply, sustainable industry, and sustainable transport. The organization acts as intermediary between the government and market forces (both industry and end-users). Novem therefore works closely with various industrial sectors (construction, energy, agricultural, transport), as well as local and provincial authorities, and research institutes (http://www.novem.org/).

- **Subsidies**

Direct or so-called transparent subsidy on energy conservation is an effective instrument. Subsidies are paid for specific conservation options in the Netherlands, either as a grant or as low rate credits. Using the REDUCE model, paying 30 percent of the investment needed for a conservation option, leads to large additional conservation in households and industries (up to 20% points extra, Uyterlinde, et. al., 1999, p 117).

Some options in the industry sector that have received subsidies and are effective in the long turn are:

- process integration to design an optimum heat exchanger network in plants producing olefins and sodium,
- introduction of selective cracking in the production of olefins,
- enhanced gas recovery in the blast oxygen furnace, and
- extrusion processes in the fodder industry.

The total budget for R&D in the energy sector was 130.7, 129.8, and 137.4 million US$ in 1995, 1996, and 1997 respectively, of which 36% allocated to energy conservation in different sectors (Ministry of Economics Affairs, 2000).

- **Regulations**

Besides financial instruments, regulatory instruments play an important role to attain further efficiency improvements. Actually these regulations can help to close the gap between the realized energy saving and the technically available potentials. Building codes, and environmental and efficiency standards are mandatory in the Netherlands. It is believed that present market shares of many conservation options in the market for individual central heating have been reached because of a combination of subsidies and regulation.

Also another, softer and therefore less intervening form of regulation is applied in the Netherlands, the so-called Voluntary Agreements (VAs) which leave large degrees of freedom for the branches or companies to decide on how an agreed energy efficiency level can be achieved. The advantage of this approach is that the companies in a sector formulate and implement the best way to achieve an agreed upon energy conservation target, instead of the government formulating explicitly how the conservation goals are to be achieved, utilizing the technological knowledge of those who know best.

- **National programs of energy efficiency**

There are several national plans on either CO2 reduction or energy efficiency improvement. The so-called Third White Paper program aims for 33% energy efficiency improvement (1.5% every year) for the period 1995-2020. Another program entitled Action Program Energy Conservation 1992-2002, aims for increasing energy efficiency improvement from 1.6% to 2% year.

- **Building codes**

Thermal energy efficiency standards for new buildings are mandatory since 1995 for dwellings and other buildings, and they are monitored. The European Commission has provided the new thermal building codes for the EU member countries, which are mandatory, and providing a building energy certificate is compulsory.

- **Labeling and efficiency standards for appliances**

These two policies are complementary. Mandatory labeling for several electrical appliances exits in all EU countries and is based on the same regulation. The regulations are based on EU directives and replaced existing regulations. Labeling on refrigerators and washing machines is compulsory, and for lamps this is planned (WEC, 2001c, p 213). Since 1999 the MEPS for refrigerators are mandatory in the Netherlands.

- **Policies on Cars**

Car ownership is lower in the Netherlands than in the surrounding countries Belgium and Germany. The tax level on car purchases in the Netherlands is very high. The normal VAT rate applies to the net price, and an additional tax of 45.2% applies to the net price. There is an annual ownership tax also, which is based on weight and type of fuel.

7.4.6 Energy Saving Prospect in Thailand

A study entitled "Thailand energy strategy and policy" has estimated the economic potential of energy saving in Thailand up to 2025 (ERI, 2000). It is based on a set of efficiency assumptions for a business as usual scenario (BAU), that represents the energy demand associated with the natural development of market forces, and the effects of currently adopted Thai energy policies and strategies.

Table 7-8. Energy conservation potential in Thailand

Sector	Consumption pattern in 1998		Energy saving in 2025	
	Share in %	MTOE*	MTOE	% of 1998
Transport	39	17.59	12.77	73
Industry	32	14.44	6.96	48
Residential	21	9.47	1.38	15
Commercial	4	1.80	1.64	91
Agricultural	3	1.35	0.25	19
Total	100	45.12	23.00	51

* The primary energy demand is 56.4 MTOE (BP 2001), considering a 20 percent for energy sector the total final energy demand is split by sectors;
Source: Energy Research Institute, 2000.

A conservation case considering all conservation options is used to estimate the demand for energy in each main economic sector, this to estimate the total conservation potential. Table 7-8 shows the energy conservation potential in 2025 as a percentage of energy consumption in 1998. The most promising sectors for conservation are commercial and transport in which the conservation potential in 2025 is estimated at 90.8% and 72.6% of 1998's consumption respectively. The total amount of energy that can be conserved in 2025 is expected to be about 51% of the consumption in 1998.

Table 7-9. The cumulative reduction as percentage of BAU consumption [%]

Year	Transport	Industry	Commercial	Residential
2000	2.4	1.0	0.2	0.1
2005	5.7	4.0	1.9	0.8
2010	10.1	8.0	6.1	2.0
2015	15.5	14.0	12.5	3.2
2020	21.8	18.0	16.1	3.7
2025	29.6	21.0	18.9	4.2

Source: Energy Research Institute, 2000

Thailand's conservation goals for 2025 are much less than the savings potential, see Table 7-9. The percentages show the cumulative reduction of energy as a percentage of a sector's BAU consumption for five-year periods. In the transport sector the cumulative percent of conservation is estimated to be about 29.6% of the BAU consumption. The energy savings potentials in industry and commercials are expected to be 21.0% and 18.9% of the BAU consumption in 2025 respectively. Note that primary energy consumption of Thailand has been about 56.4 million BOE in

1998. So, the ratio of energy savings potential to energy consumption of 1998 is about 40%.

7.4.7 Energy Saving Policies in Thailand

The energy conservation strategy in Thailand encompasses a combination of pricing, information and awareness, financial and technical incentives, assistance, and mandatory regulation. Various types of regulation (compulsory, voluntary and complementary) are used in Thailand. Minimum efficiency standards for new fluorescent lamps, and energy reporting, audit and action plan requirements for designated buildings and factories are among the mandatory regulations. The promotion of the purchase of energy efficient equipment, and the associated financial incentives are among the voluntary regulations. Energy management training programs, general awareness programs, technology demonstrations, energy efficiency research and studies are part of the complementary instruments in Thailand.

Table 7-10. Prices of petroleum products in Thailand in 2002 US$ per liter

Petroleum products	End-user	Tax	As % of price
Gasoline	0.35	0.13	35.92
Kerosene	0.36	0.10	28.08
Heavy diesel	0.31	0.09	29.51
Light diesel	0.30	0.09	30.95
Fuel oil	0.23	0.02	10.10

Source: NEPO, 2002a and author's calculations.

- **Prices and taxes**

The prices of energy carriers differ from the border prices. The domestic prices of petroleum products include many taxes and levies. To the ex-refinery prices a 10% excise tax, a municipal tax, and a contribution for an oil fund and a conservation fund result in the wholesale prices. The consumer prices, see Table 7-10, further include a value added tax and a marketing margin.

Compared to prices in Europe, Thailand's prices are relatively low, but they are considerably higher than the international free market prices. These prices result in an acceptable IRR for many conservation projects, and at the same time are sources of funding for energy conservation projects.

- **Energy efficiency agencies**

The National Energy Policy Office (NEPO) is responsible for financing energy conservation policies via the Energy Conservation Promotion (or ENCON) Fund (NEPO, 2002a).

- **Subsidies**

Subsidies are funded out of the oil fund and the conservation fund. Resources from these funds are allocated to many conservation projects, for specifics see NEPO (2002b). The size of the funds from tax on petroleum products was about $350 million in 1999 and the allocations from the funds are to the private as well as the public sector. The funds provide financial assistance to cover up to 50% of the cost of energy conservation plans, with a maximum of US$ 12,000 (WEC, 2001a, p 93). Applying the simple payback method shows that on average the payback time of investments in government buildings, designated buildings, and factories is about 2 years (WEC, 2001b, p 152).

- **Building codes**

Thermal energy efficiency standards for buildings are mandatory and the provision of an efficiency certificate is required since1995.

- **Labeling and efficiency standards for appliances**

Labeling of refrigerators and air conditioners is compulsory; the latter labeling scheme is based on the one used in Australia. Also voluntary comparison labeling programs exist and have proved their effectiveness (WEC, 2001a, p 72).

7.4.8 Comparing the three countries

Conservation options are mostly analyzed per economic sector and as a result conservation potentials are therefore estimated per economic sector rather than per energy carrier. Most studies use a modeling framework to compare the conservation scenarios that result from policy changes with the BAU scenario.

Table 7-11. Economically viable energy conservation potential as a percentage of consumption in the base year or baseline forecast [%]

Country	Industry	Housing	Service	Transport	Agriculture	Total	Note
UK	38.0	30.0	24.0	69.0	-	-	Conservation in 2020, base year 1996
Netherlands	28.5	44.0	59.9	28.2	76.0	41.0	TNO: Conservation in 2015, base year 1986
Netherlands	35.0	64.0*	65.0	45.0	73.0	49.0	ICARUS: conservation in 2015, base year 1990
Netherlands	17.0	10.0-30.0	-	-	-	-	REDUCE: Conservation in 2020, baseline forecast
Thailand	48.3	14.6*	90.8	72.3	18.9	50.9	Conservation in 2025, base year 1998

* Residential.

There are two ways to present the conservation potential: (i) the conservation potential can be calculated as a percentage of the BAU in each year, or (ii) the conservation potential is expressed as a percentage of the base year energy consumption. Both types of analysis have merit. However, type (ii) is most useful in case one cannot (easily) assign the conservation potential on a year-to-year basis. The latter is often the case when the analysis is based on technology specifications (the engineering or bottom-up approach).

Table 7-11 summarizes the savings potentials of the various studies. Note that we could easily add many more. However, for our analysis this is not required. We discussed these studies, which are each typical representatives of conservation studies, only to demonstrate that countries that already have a history of energy conservation and high prices (the United Kingdom and the Netherlands), as well as countries with moderate energy prices and that only recently introduced energy conservation measures, both have a large conservation potential.

All technology based studies show that over a period of more than two decades, the conservation potentials are considerable. The transportation sector seems to have the largest conservation potential, ranging from 28% to 69% of base year consumption. The service sector, except for the UK, shows a high capacity for conservation also; 24% to 90% of base year consumption. Other sectors show a considerable savings potential too, assuming the correct energy conservation policies are implemented.

Note that all studies distinguish technical and economic energy conservation estimates and that the latter are sensitive to the assumptions made on economic decision criteria. As the difference between the economic and the market potential for the UK shows, all policies require additional regulation and support on top of price incentives to make them successful.

Note that Table 7-11 does not contain the only top-down analysis based on the CENECA model. This study shows the effects of energy tax increases and of coordination between OECD countries. The role of new technologies was not introduced explicitly. The conservation potential is analyzed for fuels and electricity for industry and households, and especially industry shows a large potential (58.7% for fuels and 32.8% for electricity in case of OECD coordinated policy), but only 5.7% and 3.5% respectively for households.

However, as was pointed out by Grubb et al. (1993, 433-437), engineering studies tend to be more optimistic than top-down studies. The engineering studies tend to ignore essential feedbacks, whereas top-down studies tend to ignore the specifics of technology.

Another interesting point is to notice that Thailand, the Netherlands and the United Kingdom have a high savings potential, despite large differences in energy prices. The United Kingdom and The Netherlands have very high prices of energy, whereas energy prices in Thailand were at the time of the study similar to those in the United States.

In Table 7-12 the various policies used are reviewed. Fuel taxes are very large in the United Kingdom and The Netherlands, but less so in Thailand. In all countries there is a mix of price based policies and regulations. In all countries the government is very active in implementing energy conservation policies, and in monitoring their effects and the compliance by energy users. For the implementation and monitoring special organizations have been established that are (relatively) independent of the government. These are considered necessary to ensure the success of the energy policies.

The conservation estimations reported here are very specific; they cover different periods, are based on different sets of technologies, and use different methods. Therefore, they cannot be used for other countries, but can only be used as a crude guideline of what savings potential can be expected.

Table 7-12 Summary of energy efficiency policies

Description	UK	Netherlands	Thailand
Energy saving institutions [1]	NR	NR	N
National program on energy efficiency	Yes	Yes	Yes
Thermal Building codes	Mandatory	Mandatory and monitored	Mandatory and certificate
Labelling and energy efficiency standard	Mandatory and monitored	Mandatory and monitored	Mandatory
Fiscal measures on cars [2]	PT, RT	PT, RT	
Subsidies and incentives for clean and efficient cars [3]	EC, CC	EC	Conservation projects
Tax on fuels [4]	A, 0.91, 0.73	A, 0.71, 0.73	A, 0.13, 0.09
Energy audits [5]		D, C	D, C, G

1. N, R, and L stand for national, regional and local agencies respectively.
2. PT and RT stand for purchase tax and registration tax respectively.
3. EC and CC stand for electric cars and CNG cars.
4. A shows that tax exists for all fuels; the first and second numbers denoting tax on gasoline and gas oil in dollar per litter respectively.
5. D, C and G stand for dwellings, commercial, and Governmental buildings respectively; in some cases the cost is partly paid by consumers and in some cases the audit is conditional on receiving a subsidy; Source: WEC, 2001c.

We conclude that these countries show a large energy conservation potential. They have in common (i) good non-price regulatory policies, and (ii) an extended network of conservation institutions. They do, however, differ with respect to energy price levels and targeted energy pricing policies (providing acceptable IRRs for conservation projects). For Iran these countries can serve as an example on how to construct and implement its energy conservation policy. The case of Thailand shows that, from an Iranian point of view, extremely high energy prices are not required for a successful energy conservation policy, although the prices in the RS-scenario still seem to be low.

Next, we discuss the energy conservation potential for Iran, based on the potentials discussed above and information from preliminary studies done for Iran.

7.5 Energy Conservation Potential of Iran

In recent years energy conservation potentials for Iran have been studied and even some policy initiatives were ratified in the second (1995-1999) and the third (2000-2004) five-year development plan. The Ministry of Energy and the Ministry of Petroleum are responsible for the implementation of the energy conservation policy.

The technical and economic conservation potential has not been estimated for the Iranian economy as a whole, but some case/sector studies are available. We will use these estimates in combination with the information on other countries to guesstimate conservation potential for Iran. In what follows the energy saving potential based on current prices and regulations are discussed per sector. This will be used to guess the conservation potential for the whole of Iran, using tables 7-11 and 7-12 also.

- **Residential & Commercial sector**

The main energy carriers used in this sector are petroleum products and natural gas; their shares are 47.3% and 39.9% respectively. This sector has a high potential for energy conservation. Iran has implemented hardly any policies on efficient electrical appliances, double-glazing, residential tags, or building codes. Also awareness programs for the Residential & Commercial sector for efficient appliances and more energy efficient ways to live and cook are absent. There is no comprehensive study with estimates of the technical or economic energy conservation potential for this sector. However, with a good energy policy on prices and regulation, Iran's conservation potential in this sector in 2020 could be as high as 90% of the consumption of 2002, the base year. Note that this assumes that prices have been brought to at least the level of the RS-scenario. As a result, this conservation potential can only be tapped after 2007 when higher energy prices are in place.

- **Industry**

According to the 1995 census, the manufacturing sector with more than 50 workers comprises 2,263 establishments (SCI, 1997). The majority of these industrial establishments are active in textiles and in metallic products, both energy intensive industries with a large savings potential. Non-metallic mineral products show a large potential for energy conservation also.

The energy saving potential of the industrial sector is estimated at 7-8% of the current consumption when applying low-cost techniques. This level of conservation can be achieving during the next 5 years. In cement, glass, textiles, and food and beverages, the short run low cost conservation potentials are estimated at 10%, 10%, 8-9%, and 10% respectively. The amount of potential energy saving in 26 factories of the textile industry is estimated at about 5.8% in spinning, 4.9% in weaving, and 19.2% in the finishing industries (Ministry of Energy, 1998). The total conservation potential is estimated at 29% of the current consumption level when applying best practice technologies. This 29% can be achieved within five years. For the period till 2020 Iran's conservation potential is estimated at about 48% of the base year energy consumption.

- **Transportation**

With a share of 40% (in 1998), the transportation sector is the largest consumer of petroleum products in Iran. This sector has a high potential for energy conservation, since Iran's car fleet is highly inefficient. In order to achieve a high level of energy saving in this sector it is necessary to execute an effective conservation program. Energy saving should aim at (i) lowering the demand for trips, (ii) renewing the fleet (with more efficient cars), and (iii) changing the ratio of private use and public transportation.

Iran's fleet of gasoline cars is very old and mainly produced by domestic factories according to old specifications, based on inefficient techniques. Only about 10% of the fleet consists of new cars with modern fuel-efficient engines. The larger part of the fleet consumes 13 to 15 liter of gasoline per 100 kilometers, whereas the best practice elsewhere in the world is 5.5-7 liter.

Changing the current fleet by replacing old cars by modern efficient ones can save about 46% of the gasoline consumed in the transport sector. The saving potential of gasoline was about 32 million BOE in 1998, which is about 20% of the consumption in the transport sector.

In gas oil-consuming cars the average fuel consumption is about 40 liter per 100 kilometer, whereas it is 35 liter in developed countries (Ministry of Energy, 1999), and even less in the latest designs.

Table 7-13. Potential conservation in Iran's transportation sector, 1998

Management Method	Executive approach	Conservation (million BOE)
Fleet	Optimizing consumption of current fleet	8.20
	Replacing new cars by old	6.20
	Changing technology of car manufacturing	0.37
Passenger Traffic	Changing the pattern of Passenger developing from Tehran to other cities	3.60
	Increasing public transport	2.80
	Changing the pattern of Passenger developing from Tehran to countryside	0.45
	Increasing the share of rail road	0.30
Cargo Traffic	Decreasing mileage of cars without cargo	2.68
	Decreasing the double transporting of cargo	1.83
	Increasing the share of rail road	0.48
	Management of cargo transportation in ports	0.43
	Increasing the share of pipeline in the petroleum products delivery	0.24
Miscellanies	Developing nationwide road network	2.94
	Developing communication system	1.75
Total		32.04

Source: Ministry of Energy, 1999.

The conservation potential can be further increased by developing a healthy public transport system, decreasing the numbers of cars with only one person, increasing the number of restricted traffic zones (a zone with limited access for private cars) in the big cities, and improving fuel quality.

A study by the Department of Energy Affairs of the Ministry of Energy (1999) has shown that a cost-effective potential of conservation related to road inter-state and total road transportation were 22.9 and 32.0 million BOE respectively. The latter figure includes the potential of conservation in transportation in the cities, but does not include intra state traffic. Their ratios of potential conservation to energy consumption were about 13% and 19% respectively in 1998. Table 7-13 shows the estimation of potential conservation in the road transportation.

We can conclude that the long-term savings potential for this sector is very high, especially with additional fuel price policy and fiscal incentives for public transport. Based on international studies by the World Bank and reported by the Ministry of Energy (1999) Iran's energy conservation potential in 2020 could be more than 70% of the base year consumption.

- **Agriculture**

There are no estimations of the conservation potential in Iran's agriculture sector. This sector is not very energy intensive and to some extent its methods are very traditional. Therefore, it is not expected that this sector can contribute much to the conservation potential. Based on Table 7-110 we consider the lowest estimated value of 19% of the base year consumption as the energy conservation potential.

- **Energy conservation as a percentage of total final energy demand**

Since Iran has not seriously implemented energy conservation measures yet, the conservation potential in different sectors in Iran is most likely higher than in the countries reviewed. Based on Table 7-11 and the discussion of the Iranian situation it seems save to assume that the energy conservation potential in 2020 is 40% of total final energy consumption in 2002 (the base year). Of course, we assume that the energy prices in Iran are increased to the border prices and are kept on that level.

We want to investigate if more energy conservation is feasible and whether this could result in more economic benefits. To be on the conservative side and given the fact that Iran's increased energy prices are still relatively low, we assume that the conservation potential of total final energy demand is 32% of the final energy demand in the RF scenario in 2020.

Note that this 32% energy demand reduction in 2020 of RF scenario is equivalent to the 40% final energy demand reduction of the final energy demand in the year 2002 in the RS scenario.

- **Power generation and transmission**

Iran's power sector shows high levels of energy loss. In electricity generation, the average efficiency is much lower than the best practice in other parts of the world. Therefore, a tremendous amount of energy can be conserved in the power sector. Table 7-13 represents the average efficiency of different types of power plants in 1998. The average efficiency of the steam plants included in the grid is 33.5%, and only 29.5% for the plants that are operated outside the grid. In these plants the maximum achievable efficiencies are 39% and 36% percent respectively.

The efficiency of gas turbine plants lies in the range of 22.6% to 30.1%. The best available technology is the combined cycle technology, which can achieve efficiencies of more than 40%.

The overall efficiency of Iran's electricity generation is currently about 30%. The completion of the steam phase of CCGT plants would improve the overall efficiency. It is assumed that from year 2008 till 2020 the efficiency is 10% higher than in the RS scenario. This is translated to an average overall efficiency of 33%.

Table 7-13. Efficiency of thermal power plants in Iran in 1998 [%]

Type	System	Average Efficiency	Maximum Efficiency	Minimum Efficiency	No. of Plants
Steam	Integrated in grid	33.5	39.0	23.0	15
	Out of grid	29.5	36.0	25.1	3
Gas turbine	Integrated in grid	30.1	41.0*	16.2	22
	Out of grid	22.6	25.8	16.2	10
Diesel	Integrated in grid	30.0	-	-	-
	Out of grid	31.0	-	-	-

Source: Ministry of Energy, 1999.

* Gillan Combined Cycled Gas Turbine (CCGT) power plant.

Table 7-14. Transmission and distribution losses and self-consumption of plants [%]

Year	Transmission Loss	Distribution Loss	Self Consumption	Total
1967	1.2	14.0	5.5	20.7
1987	3.3	9.3	4.8	17.4
1997	3.8	11.2	5.0	20.0
1998	5.1	10.4	4.6	20.1

Source: Ministry of Energy, 1999

Decreasing the loss of electricity transmission and distribution is another opportunity for energy conservation in the electricity sector; Table 7-14 shows that about 20% of gross electricity is lost and/or consumed in the transmission and distribution systems. We assume that these losses can be decreased to 15% of gross electricity generated, which is still far from the losses in efficiently operated transmission systems in Europe, where losses and own consumption are mostly below 10%.

- **Oil refineries**

The loss of fuels in Iran's oil refineries is on average about 12.2% of the oil feed; also see Eq. 6.37. The lowest loss rate in refineries in the world is about 5%. Therefore, it is assumed that Iranian refineries can save at least 2.2% more, which means that only 10% of the feed will be lost. This is equivalent to a transformation factor of 1.11 Eq. 6.37.

7.6 Further Improving Iran's Energy Basket

As was mentioned before, under the RS scenario energy and economic efficiency are expected to improve considerably with respect to the BAU scenario. (Total energy savings were 17% of BAU.) In Section 7.4 we showed that there is more room for energy conservation in Iran and in Section 7.3 we showed that, even in the RS scenario, Iran's domestic price of one composite barrel of petroleum products in 2020 would still be below the current price in the US. With the current US price among the lowest in the world, especially when compared to European prices, there is room for upwards price adjustments in Iran. This can be used to support a more comprehensive energy conservation policy, the design of which is beyond the scope of this research. What we can do, however, is analyze the effect of the conservation potential indicated for Iran in Section 7.5. We call this the improved or IM scenario.

The IM scenario is energy conservation that, in our opinion, can be achieved on top of the RS scenario with good policy support, but without additional fuel price increases. Since the fuel price increases will be the main drive for energy savings in the period 2002-2007, we assume that the additional energy conservation would be realized from 2008 to 2020. We will use the distribution of fuels in the energy basket of 2007 to distribute the overall energy savings over the different fuels. Note that all formulas are based on BOE, and that for notational simplicity the conversion factors are not stated. The conversion factors used are those reported in Chapter 6.

As we concluded in Section 7.5 we assume that an additional 40% of the final energy demand in 2002 under the RS scenario can be saved by 2020, that is total final energy demand under the IM scenario $TFED_{2020}^{IM}$ is the same variable under the RS scenario minus 40% of the final demand in under the RS scenario in 2002

Dj_t^{RS} denotes the annual fuel demand by power plants per fuel type in the RS scenario.

Conservation in the transmission and transformation is formulated as follows

$$ETCO_t^{IM} = \left(\frac{ELEC_t^{RS}}{EF_t^{RS}} - \frac{ELEC_t^{IM}}{1.0625EF_t^{RS}} \right) * 100 \tag{7.7}$$

$ETCO_t^{IM}$ denotes the amount of electricity conserved in the IM scenario due to improved transmission and distribution. $ELEC_t^{IM}$ is calculated as discussed in Section 7.5. To calculate the gross electricity demand i.e. the gross production of electricity at power stations we use $\frac{ELEC}{EF^{RS}}$ as discussed in Chapter 6. EF^{RS} in 1998 was 80%, based on 20% losses and own use in distribution and transmission. With a 5% point improvement we now have 15% losses and own use. To correct for this we introduce the factor 85/80 = 1.0625.

Using equations (7.6) and (7.7) the improved demand for energy carriers in the power sector can be calculated. Total energy conservation in electricity system is deducted from the fuels demand based on the fuel shares (Sj_t) in the RS scenario.

$$Dj_t^{IM} = (Dj_t^{RS} - Sj_t^{RS}(EGCO_t^{IM} + ETCO_t^{IM})) \text{ with } j \in \{\text{GSOILE, FOILE, NGE}\}$$

$$\text{and } \sum S_j^{RS} = 1 \tag{7.8}$$

The total demand for petroleum products in the IM scenario can be calculated as

$$TPPC_t^{IM} = \sum_i Di_t^{IM} \tag{7.9}$$

with $i \in$ {JETF, LPG, GSLN, KER,GSOIL, FOIL, GSOILE, FOILE}. Taking into account the improvement in the refinery sector, the primary demand for oil becomes

$$DOILD_t^{IM} = 1.11 \ TPPC_t^{IM} \tag{7.10}$$

Using (7.5) and (7.8), the primary demand for natural gas can be calculated as

$$TFED_{2020}^{IM} = TFED_{2020}^{RS} - (0.40TFED_{2002}^{RS}) \tag{7.2}$$

We assign this savings potential to the period 2008-2020 using a constant growth rate

$$TFED_t^{IM} = TFED_{2007}^{RS} e^{r(t-2007)} \text{ and } r = \ln\left(\frac{TFED_{2020}^{IM}}{TFED_{2007}^{RS}}\right)/13, \ t = 2008,..,2020 \tag{7.3}$$

This results in the total final energy conservation $TFCO_t^{IM}$

$$TFCO_t^{IM} = TFED_t^{RS} - TFED_t^{IM} \tag{7.4}$$

The amount of conservation calculated in (7.4) is split over petroleum products, natural gas, and electricity using the shares of these fuels in the RS scenario. The improved energy basket is defined as

$$Dj_t^{IM} = \left(Dj_t^{RS} - COj_t^{IM}\right) \tag{7.5}$$

with Dj_t^i the final demand for energy carrier j at time t under scenario $i \in$ {RS, IM}; COj_t^{IM} the amount of energy carrier j conserved at time t under the IM scenario; and $j \in$ {JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC }.

The conservation in the power sector is calculated for generation, and transmission and distribution according to the conservation figures of the previous section. The reduction in fuel demand due to the 10% increase in efficiency can be expressed as

$$EGCO_t^{IM} = 0.1\varepsilon_{generation}^{RS} \sum_{j=FOILE,GSOILE,NGE} Dj_t^{RS} \tag{7.6}$$

$EGCO_t^{IM}$ is the amount of electricity generation conservation under the IM scenario; $\varepsilon_{generation}^{RS}$ is the overall efficiency of the power production system in the RS scenario.

The final demand for petroleum products in 2020 is expected to be 850,000 BOE per day, the same level as in 1992. The total conservation on final energy demand in the IM scenario will amount to 4.6 billion BOE compared to RF scenario, which is 1.5 billion BOE above the RS scenario.

In the IM scenario, it is expected that the efficiency of energy sector is improved, which contributes a tremendous amount of energy to the savings. Figure 7-23 shows that in the IM scenario the demand of oil decreases and is about 1 million barrel per day in 2020, while it slightly increases in the RS scenario and demand in 2020 is 1.33 million barrel per day. Because of the domestic gas market development policy, the demand of gas increases in both scenarios, and other fuels can be neglected.

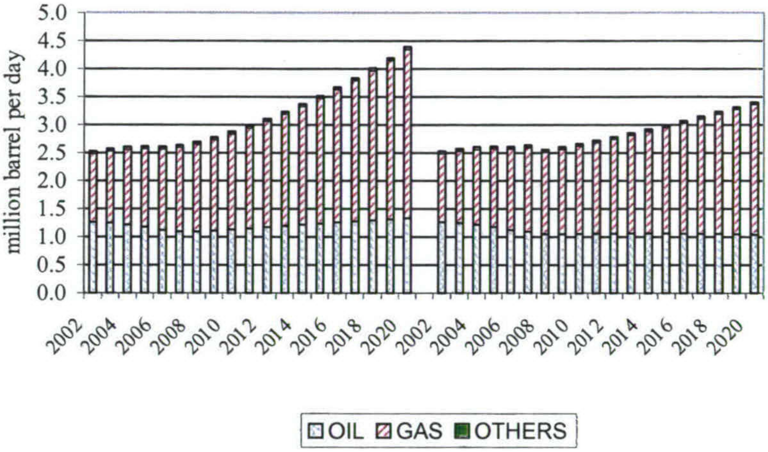


Table 7-23. Total primary energy demand in RS (left) and IM (right) cases

Total primary energy demand (*TPED*) in 2020 is expected to be 3.41 million BOE per day in the IM scenario, against 4.39 million in the RS scenario, a difference of 980,000 BOE per day. The total amount of energy conserved in the IM scenario is 6.9 billion BOE against 4.5 billion BOE in the RS scenario, of which on average 40% is achieved in the energy transformation sector.

Note that the effect of conserving one BOE of final energy demand results in a much larger overall savings due to lower demand in the (inefficient) power and refinery sectors. One BOE of conservation in the final energy demand sectors results in 0.56 BOE additional conservation in the energy sector in the IM scenario.

Using (7.5) and (7.8), the primary demand for natural gas can be calculated as

$$NGT_t^{IM} = NG_t^{IM} + NGE_t^{IM} + NGR_t^{IM} \tag{7.11}$$

The demand for natural gas in refineries (NGR_t) is calculated as explained in Chapter 6. We assume no conservation potential in hydro electricity and in the primary demand for solid fuels.

7.6.1 Impact of Extra Energy Conservation

From the above it is obvious that the effects the extra energy savings have on the Iranian economy in the IM scenario cannot be analyzed within the model. What we can do, however, is calculate the value of the extra oil available for export and compare the main variables, such as, final and primary energy demand, domestic oil demand, oil export, oil revenue, the amount of conservation, and energy intensity, under the different scenarios are discussed.

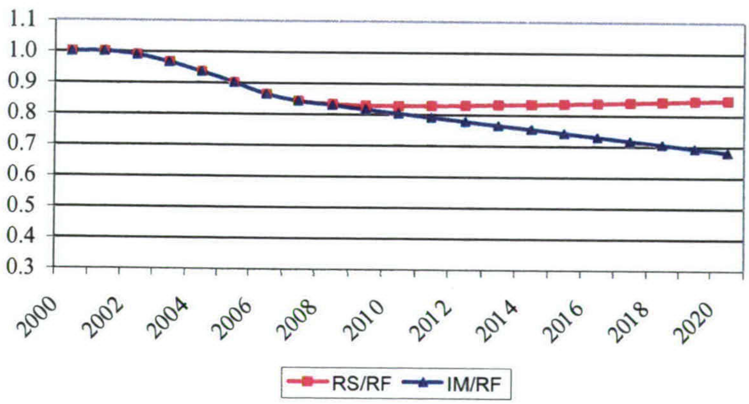


Table 7-22. Total final energy demand in RS and IM cases over the baseline

Total final energy demand in 2020 is 4.5, 3.8, and 3.1 MBOE per day in RF, RS, and IM scenario respectively. Figure 7-22 shows that in the IM scenario the *TFED* is 68% of the BAU scenario, whereas in the RS scenario this ratio is considerably higher (85%). The main portion, about 68%, of the conservation originates from natural gas; about 30% originates from petroleum products.

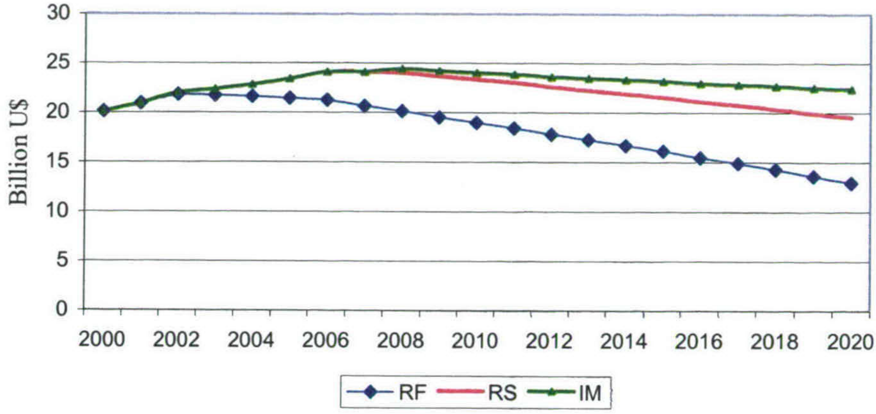


Figure 7-24. Oil revenue in the three scenarios

Figure 7-24 compares the oil revenues (OILR$) in the three scenarios. In all scenarios the oil revenues decrease, but in the IM scenario the rate of decrease is very small. The revenue in 2000 is US$ 20.17 billion, which will increase to US$ 22.43 billion in 2008, and then will be rather constant to end at US$ 22.38 billion in 2020. The revenue in RF and RS cases are 12.96 and 19.56 billion dollar in 2020 respectively.

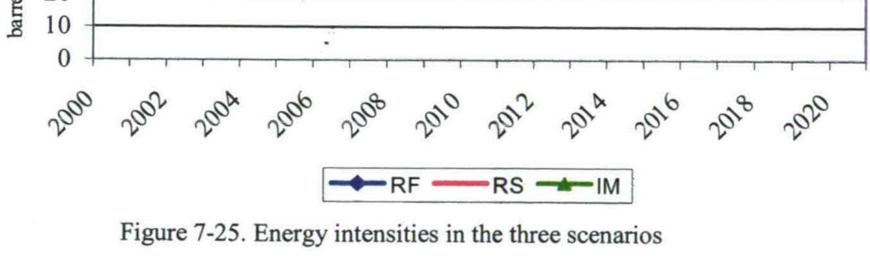


Figure 7-25. Energy intensities in the three scenarios

Finally, we compare the energy intensities of the three scenarios (Figure 7-25), since this is a widely used indicator. For the IM scenario, we use the GDP of the RS scenario to calculate the energy intensity for this scenario. Note that this will overestimate the energy intensity for this scenario, since the GDP in the IM scenario is expected to be higher than in the RS scenario.

7.6.2 Impact of Extra Conservation on GDP

As was mentioned before, more energy conservation could be achieved from 2008 to 2020 through non-pricing policies that support the new pricing policy. The model developed in Chapter 6 is not detailed enough to analyze the effects of the IM scenario. However, a way to indicate the effects additional energy conservation has on the Iranian economy can be obtained by introducing the excess dollar oil income from additional oil export in the macro-economic model. Since the effect a higher GDP has on fuel demand is partly neglected, this effect might be overestimated somewhat.

Note, however, that we do not account for the improved financial policy

economy and its trade position.

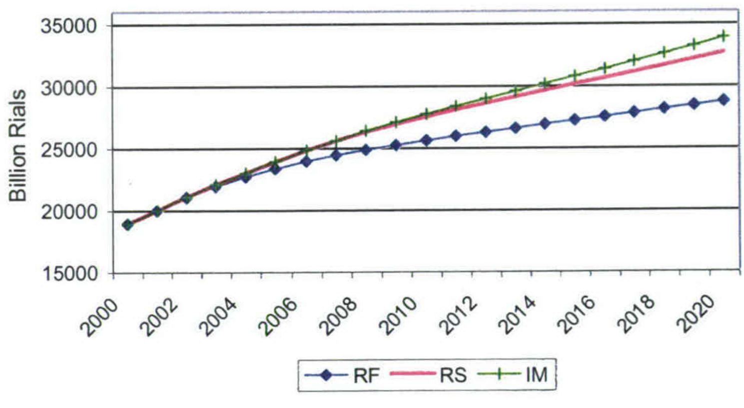


Figure 7-26. Real GDP in the three scenarios

Figure 7-26 shows the effect of the extra oil revenue on GDP growth in the RF, the RS and the IM scenario. A considerable improvement in GDP growth is expected in the IM case. The GDP growth is expected to be around 1% in the RF scenario when approaching 2020, 1.6% in the RS scenario, and 2% in IM scenario.

7.7 Conclusions

Increasing domestic energy prices until all implicit energy subsidies are abolished will, contrary to popular believe, fuel the economy and if supported by an adequate financial policy reduce inflation considerably. In this scenario of removing implicit energy subsidies and holding the domestic energy prices at their border prices provides a tremendous amount of funds for the government, which can be used to lower inflation through lowering liquidity growth. Furthermore, sufficient government finances will be available to compensate the poor without the need to issue new high-powered money. The lower liquidity growth will stabilize Iran's economy, with a lower Rial exchange rate volatility and inflation. Since the economy is fuelled by a larger dollar inflow due to the fact that substantially more oil is available for export, the GDP experiences a faster growth when the implicit energy subsidies are abolished.

In the subsidy-free scenario, the average annual GDP growth rate is 1.11% higher than in the BAU scenario. In the RS scenario, total earnings from oil export are expected to be US$ 423.3 billion, 1.26 times the revenues in the BAU scenario. Because of the much lower domestic inflation in the RS scenario, the value of the Rial isn't depreciating, but stabilizing around the current parity to the US$.

The performance of the energy sector is even greater. The growth rate of energy demand in the subsidy-free case is about 3%, or 1.16% lower than in the BAU scenario, despite the increased growth in GDP. Total conservation would amount to 4.56 billion BOE and staggering amount of US$ 403.04 billion in implicit energy subsidies would be saved. The energy intensity as an indicator of the economies energy performances shows a much lower growth rate in the RS scenario, depicting the fact that both, the economy and the energy sector show better performance.

Although energy prices increase quickly over the period 2002-2006, domestic energy prices in 2020 would still be much lower than the current prices in countries like the United States and Thailand. In the RS scenario the price of one composite barrel of petroleum products in Iran would be US$ 30 in 2020, whereas it is currently about US$ 44 in the United States and US$141 in the UK.

If Iran's energy pricing policy would be linked to additional conservation policies as utilized in many countries, the energy conservation potential is even much larger than in the RS scenario. We analyzed this situation also and an additional 2.33

billion BOE can be saved, leading to an additional US$ 19.36 billion in oil income over the period 2008-2020.

The additional energy savings can be achieved by policy measures, such as the installation of energy efficiency agencies, national energy efficiency programs, a reduction of losses in the primary energy sector, applying mandatory building codes and providing compulsory building certificates, labeling and efficiency standards for appliances, fiscal measures, subsidies, and a comprehensive transport policy.

The energy conservation experiences of the United Kingdom, the Netherlands, and Thailand, which combine good pricing and non-pricing policies, show that over a period of two decades up to 40% of the base year energy consumption is realistically feasible. Therefore, we conclude that by applying higher energy prices in combination with implementing good non-price policies, a much higher conservation potential is available that will result is a better performing economy. This policy is needed to prevent a rapid decrease of oil dollar revenues and the gradual collapse of the Iranian economy in the next decade.

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Chapter 8

Epilogue

8.1 Introduction

The Islamic Republic of Iran has large energy resources that can and should be used to improve its economy. Currently Iran's domestic energy policy is based on the idea that the Iranian people should, as much as possible, benefit from these natural resources, which is a good idea. However, the way this is currently implemented in Iran's domestic energy policy is wrong and hampers the efficient and effective use of the energy resources. The extremely low energy prices in Iran have led to misallocation of the valuable energy resources and actually do not benefit the Iranian people as much as they could or should. In addition the excessive domestic consumption of energy, especially petroleum products, lowers Iran's oil export capacity since Iran's oil production capacity is limited. To analyse this problem, this research aimed at identifying the strengths and weaknesses of Iran's domestic energy sector, as well as its opportunities and threats. For this a SWOT analysis was conducted for Iran's domestic energy sector. This permitted the formulation of a domestic energy policy that benefits the Iranian economy in the long-term better than the current policy does.

The SWOT analysis took into account Iran's domestic circumstances as well as international developments. Domestically Iran is characterized by strong population growth, low economic growth, and a too large government sector. In the latter many still believe that the government can control and run large parts of the economy -including the industrial sector-, an idea that in most other countries, and certainly in the economically more successful ones, has been abolished.

The SWOT analysis highlighted in a number of strategic issues for Iran in general (high inflation, high unemployment, etc.), which cannot or only partly be resolved by an improved domestic energy policy, and strategic issues that are at the core of Iran's domestic energy policy and can contribute to resolving Iran's economic problems. The latter, improving domestic energy prices and other measures to save energy became the central focus of our analysis. The main conclusions and future research will be discussed next.

Before we discuss these issues, it is important to emphasize again that Iran is located in a geographical part of the world with many political problems -to name a few, the Palestinian problem, Iraq, and Afghanistan-, that can easily change the political setting for our analysis drastically. However, we are convinced that, especially with the worst-case scenario in place, Iran has to implement the new domestic energy policies suggested and analysed here. Only then the Iranian people will benefit more and longer than they do now from Iran's rich non-renewable resources and Iran will have sufficient funds to invest in its non-oil based economy.

This chapter is organized as follows, Section 8.2 summarizes the results, and Section 8.3 looks at future research.

8.2 Summary of Results

Despite the fact that energy intensities are falling and there is a worldwide search for alternative forms of energy, the international setting for oil trade remains favorable in the long term. It will, however, take a very long time before an infrastructure for the widespread use of other forms of energy is in place and affordable for all. This is particularly true for the use of petroleum products in transport. The current falling trend in energy intensity, especially in the rich countries, does not mean that absolute energy demand shows a negative growth rate, but it is mainly the result of a faster growing and less energy intensive service sector. On the contrary, with the Asian economies (especially China) growing fast, energy markets in general and international oil markets in particular are expected to show continuous growth, despite international agreements on greenhouse gas emissions, such as the Kyoto protocol.

With the reduction of oil supply from outside OPEC, the importance of supply by OPEC will increase. Iran is an important member of OPEC and its production share will remain regulated within OPEC. However, increasing Iran's future oil production or even stabilizing it at its current level will be difficult, because its main reserves passed their peak production. Keeping the oil flowing will require dollar inflow for capital investment in production capacity.

The SWOT analysis showed a number of weaknesses when evaluating Iran's internal conditions in general and its domestic energy market in particular. Clear general weaknesses are a high population growth rate, large (hidden) unemployment, low capital formation, slow economic growth, and double-digit inflation resulting in decreasing real per capita income. Furthermore, the main proportion of Iran's total population is living in big cities, requiring a growth of employment in Iran's manufacturing and service sectors.

The average growth rate of domestic energy consumption has been 4.2% for the period 1977-1998, while GDP showed a growth rate of about 1.2% over the same period. Final and primary energy consumption has increased rapidly in comparison with GDP, indicating that energy has been consumed inefficiently in Iran.

The main cause for this strong growth in energy demand is Iran's energy pricing policy. In Iran energy prices are set by the government, but in an inadequate manner. For many years, nominal energy prices in Iran were kept constant or increased only moderately. Due to the high inflation rate, real energy prices decreased continuously, with the exception of gasoline of which the price was drastically increased once in 1980. In 1998 the average nominal price of petroleum products was 16 Rial or 1.3 US$-cent per liter and in 1999 the price of premium leaded gasoline was about 90 US$-cent in OECD Europe against 4.2 US$-cent in Iran.

Iran's energy pricing policy has led to huge implicit subsidies on energy. Domestic energy prices in the year of 2000 were between 5 percent and 27 percent of international prices for fuel oil and gasoline respectively. Based on border prices these subsidies vary between US$ 9.3 and US$ 14.4 billion, which is about 10 to 15% of total GDP. Iran, as an oil–based economy, earns 75% of its foreign revenue and about 50% of its government budget from oil export.

Low energy prices also resulted in an inefficient and ineffective power and oil refining sectors. Under normal conditions these sectors should be able to generate money for their own investments. However, due to the low prices for their products they have become dependent on government funding. With the many economic problems Iran is facing, and the government's limited amount of financial resources, these sectors have been under funded and have become less and less efficient, adding to Iran's list of problems.

Iran has implemented only one policy to reduce domestic reliability on oil products. Iran is endowed with large natural gas reserves (24.3 trillion cubic meter or 857 trillion cubic feet, which is 15.8% of total world reserves), which are much more difficult (and thus costly) to export than oil. For many years Iran has invested in a domestic gas infrastructure, and in the use of gas in secondary oil recovery. As a result the share of oil-based products in total energy demand has decreased from over 80% in 1974 to less than 58% in 1998. However, during the same period final demand still grew from 0.32 million barrels per day to 1.21 million.

Besides difficulties related to energy pricing and non-optimal usage, Iran's domestic energy sector is characterized by many organizational problems.

First, there is a complex and centralized structure of decision preparation and decision taking that does not favor quick responses to changes in domestic or international energy markets. The current policy structure also hampers negotiations with foreign oil companies and others, whose expertise is needed to improve Iran's energy sector capabilities.

Second, ones the governmental bodies agree, there are several ministries, of which the Ministry of Petroleum and the Ministry of Energy are the most prominent, that have to implement the policies. The National Iranian Oil Company or NIOC is Iran's most important executive body in the field of energy and is a subsidiary of the Ministry of Petroleum. The NIOC is very large and very powerful, and policy initiatives are often formulated by this organization, since it has all available information on energy matters. But due to the large and very diverse nature of NIOC's activities decision-making within the NIOC is also a slow and time-consuming process. As a result of this organizational structure, decision-making that in other countries is done by several independent (not necessarily private) energy companies is in Iran the domain of one company, which is again intertwined with ministerial decision-making. This has led to very slow and often counter productive decision-making, and incoherent policy implementations.

An issue that was not studied in this research, but needs to be considered is the liberalization and eventually privatization of many of the energy related activities that are now part of the NIOC. Such policies would undoubtedly improve the effectiveness and efficiency of the domestic energy sector.

Our analysis has resulted in three important strategic planning issues. First, the gas for oil substitution policy has to be continued. Second, the domestic energy prices need to be increased and this pricing policy needs to be supported by a rigorous non-price energy policy, including building codes, energy labeling for appliances, etc.

Third, restructuring the domestic energy sector is a necessity in order to improve decision-making at all levels. The domination of all energy matters by the government sector has to be abolished.

Natural gas resources are widely available in Iran, cheap to produce, but difficult to export. The gas for oil substitution policy is one of the ways to reduce the growth in domestic oil consumption and thus increase the amount of oil available for export.

As we have shown, increasing domestic energy prices to border prices will abolishes the implicit subsidies, and will, contrary to popular belief, fuel the economy, and if supported by an adequate financial policy reduces Iran's rampant inflation considerably. In this scenario, removing implicit energy subsidies and pricing domestic energy at border prices will provide large funds for the government, which can be used to lower inflation by lowering the growth in liquidity needed for government funding. Furthermore, sufficient money will be available to compensate the poor. The lower liquidity growth will stabilize Iran's economy, with a lower Rial exchange rate volatility and inflation. The lower domestic energy demand results in a considerable increase in oil revenues, which will fuel a faster growth of the economy. Within two to three years these positive economic effects of the domestic energy price increases counterbalance the expected increase in inflation. This is in strong contrast to popular belief in Iran.

In the RS (removing subsidy) scenario the annual GDP growth rate is 1.11 percent higher than in the business as usual or RF (reference) scenario. In the RS scenario total earnings from oil export is expected to be 423.3 billion US$, 1.26 times the revenues in the RF scenario. Because of the much lower domestic inflation in the RS scenario, the value of the Rial does not depreciate, but stabilizing around the current parity to US$.

Based on our quantitative analysis for the period 1998-2020, the growth rate of energy demand in the RS scenario is about 3%, 1.2% lower than in the RF scenario. Total energy conservation amounts to 4.56 billion BOE and US$ 403 billion in implicit energy subsidies will become available for the government.

Although in the RS scenario energy prices increase quickly between 2002 and 2007 to reach border prices, domestic energy prices in 2020 would still be much lower than the current energy prices in most other countries. In the RS scenario the price of one composite barrel of petroleum products in Iran would be about 30 US$ in 2020, whereas it is currently about $44 in the US and $141 in the UK.

Additional conservation policies that supplement the pricing policy will enhance the effect of the pricing policy. An additional 2.33 billion BOE can be saved, leading to an additional US$ 19.4 billion in oil income over the period 2008-2020.

The additional energy savings can be achieved by policy measures, such as the installation of energy efficiency agencies, national energy efficiency programs, a reduction of losses and waste in the primary energy sector, applying mandatory building codes and compulsory building certificates, labeling and efficiency standards for appliances, fiscal measures, subsidies, and a comprehensive transport policy.

The removal of the implicit energy subsidies in the period 2002-2007 and applying targeted conservation policies afterwards will improve Iran's economic performance considerably. This policy is needed to prevent a rapid decrease of oil dollar revenues and the gradual collapse of the economy in the next decade.

8.3 Future Research

Almost every Iranian has an opinion about how Iran's energy resources should be used; however, only a few contribute to this discussion based on facts and scientific analyses. Through this research, substantial effort was spent to improve the level of the discussion about Iran's domestic energy sector, using sound scientific methodologies. Iran's domestic energy sector was analyzed and it was shown that by better policy, especially drastic price increases, it can be improved considerably. As a result substantial energy conservation becomes feasible. Energy that can be exported, and the extra revenue so obtained can contribute considerably to Iran's economic development. Despite the fact that our analysis is a comprehensive one, it is still only a partial analysis. The model used to analyze the domestic energy sector includes only a rudimentary macro model and the financial sector is not endogenous. Furthermore, the model is based on data that cover several difficult economic times (a revolution, a war, and a boycott by the U.S.A), and although the estimated equations of the model are relatively stable many more detailed studies as well as a more rigorous economic evaluation is required.

Further research must include detailed studies of the power sector and the refinery sector to map out plans for improvement. Detailed analyses of Iran's technology base in these sectors, but in building and transport also, are required when energy saving and technology improvement policies will be developed. As we have shown, all other improvements of Iran's domestic energy sector would be futile without drastic increases of Iran's domestic energy prices. An often used argument against domestic price increases is that the poor would suffer. However, it has been shown that the price increases would supply the government with sufficient means to curtail inflation and the money to compensate the poor. (The latter needs a more detailed study also.)

Note that the rich would after a few years benefit much more from this policy than the poor will ever do, because of the decrease in inflation and Iran's overall economic improvement.

Only through a sound domestic energy policy, with increased energy prices at its core, the Iranian people will be able to benefit more and longer from Iran's natural resources. If this policy is not implemented Iran will suffer the economic and social consequences in ten to fifteen years time.

Appendix A: Overview of the Model

KEYNESIAN MODEL

Estimated equations

$$\begin{aligned}
LOG(CP) &= -7.899 + 0.137 * LOG(GDEM82) + 0.663 * LOG(POP) \\
&\quad + 0.152 * LOG(R\$) + 0.376 * LOG(CP(-1)) \\
LOG(I) &= 0.492 + 0.281 * LOG(R\$) + 0.158 * LOG(CAPIM\$) + 0.665 * LOG(I(-1)) \\
LOG(G) &= -0.309 + 0.214 * LOG(R\$) + 0.150 * LOG(GDEM82) + 0.774 * LOG(G(-1)) \\
LOG(M) &= 4.070 + 0.205 * LOG(R\$) - 0.023 * TREND + 0.847 * LOG(M(-1)) \\
&\quad - 0.461 * LOG(M(-2))
\end{aligned}$$

$$LOG(CPI) = 5.179 + 1.149 * (LOG(LIQUID) - LOG(GDPM82)) + [AR(1) = 0.235]$$

In the IM scenario the following equation is used for the period 2002-2006

$$LOG(CPI) = 5.179 + 0.018 LOG(PENG) + 1.149 (LOG(LIQUID) - LOG(GDP)) + [AR(1)=0.235]$$

Identities

$$\begin{aligned}
GDEM82 &= CP + I + G + X - M \\
GDPM82 &= 1826.334 + 0.807 * GDEM82 - 1019.602 * DGDE + 81.542 * TREND \\
X &= AERC * (R\$ - FDI) \\
R\$ &= OILR\$ + NOILR\$ + FDI - BE \\
OILR\$ &= (XOIL * 365 * POIL) / 1000 \\
XOIL &= (QOIL) - (DOILD / 365)
\end{aligned}$$

In the IM scenario the following additional equation is used for the period 2002-2006

$$LIQUID = 1.15 * LIQUID(-1) - 0.5 ER^{RS} * (SUBSID^{RF} - SUBSID^{RS})$$

Exchange rate equation

$$LOG(ER) = 1.670 + 0.386 * LOG(CPI) - 0.368 * LOG(R\$) + 0.606 * LOG(ER(-1))$$

Converting US$ into real Rial

$$LOG(AERC) = 6.244 - 0.697 * LOG(POIL) + 0.133 * LOG(AERC(-1))$$

FINAL ENERGY DEMAND MODEL

$$\begin{aligned}
LOG(JETF) &= -10.640 + 0.136 * LOG(PASA) + 0.541 * LOG(LOADA) \\
&\quad + 1.069 * LOG(GDPM82) - 0.047 * TREND + 0.207 * LOG(JETF(-1)) \\
LPG &= -1798.973 - 31.832 * RPLPG + 0.00053 * NRHOUS + 0.0618 * GDPM82 \\
&\quad + 0.601 * LPG(-1) \\
LOG(GSLN) &= -4.429 - 0.0236 * LOG(RPGSLN) + 0.354 * LOG(SGSCAR) \\
&\quad + 0.425 * LOG(GDPM82) - 0.114 * DGSLN + 0.483 * LOG(GSLN(-1)) \\
LOG(KER) &= -0.1507 - 0.142 * LOG(RPKER) + 0.618 * LOG(GDPM82) \\
&\quad + 0.380 * LOG(KER(-1)) \\
LOG(GSOIL) &= 0.115 - 0.069 * LOG(RPGSOIL) + 0.221 * LOG(GDPM82) \\
&\quad + 0.781 * LOG(GSOIL(-1))
\end{aligned}$$

LOG(FOIL) = 2.172 - 0.108 * LOG(RPFOIL) + 0.053 * LOG(GDPM82)
+ 0.702 * LOG(FOIL(-1))
NG = 0.650 - 0.0523 * RPNG + 3.004E-06 * NNGC + 0.759 * NG(-1)
LOG(ELEC) = 0.675 - 0.075 * LOG(RPELEC) + 0.138 * LOG(NELECC)
+ 0.831 * LOG(ELEC(-1))

Additional equations

LOG(SGSCAR) = - 0.371 + 0.214 * LOG(GDPM82) - 0.0046 * TREND
+ 0.894 * LOG(SGSCAR(-1))
LOG(SGOCAR) = - 11.149 + 0.212 * LOG(GDPM82) + 0.745 * LOG(POP)
- 0.0136 * TREND + 0.700 * LOG(SGOCAR(-1))
LOG(NELECC) = 0.543 + 0.943 * D(LOG(NHOUS)) + 0.944 * LOG(NELECC(-1))

PRIMARY ENERGY DEMAND MODEL

Quantity of thermal electricity generated (million kWh)

GEG = ELEC / (EF / 100)
HEG = (SH(-1) / 100) *0.9999 * GEG
SH = (HEG / GEG) * 100
QTEG = GEG - HEG

Fuel demand

LOG(FOILE) = 1.435 + 0.396 * LOG(QTEG) + 0.755 * LOG(FOILE(-1))
- 0.435 * LOG(FOILE(-2))
LOG(GSOILE) = 0.627 + 0.358 * LOG(QTEG) - 0.549 * DGSOILE
+ 0.424 * LOG(GSOILE(-1))
LOG(NGE) = - 2.898 + 0.328 * LOG(QTEG) + 0.725 * LOG(NGE(-1))

Domestic demand for energy carriers in million BOE

JETFB = (JETF * 6.063) / 1000
LPGB = (LPG * 4.166) / 1000
GSLNB = (GSLN * 5.525) / 1000
KERB = (KER * 5.928) / 1000
GSOILB = (GSOIL * 6.189) / 1000
FOILB = (FOIL * 6.502) / 1000
NGB = (NG * 6.388)
ELECB = (ELEC * 630.38 / 1000000)

Total final energy demand in million BOE

TFEDB = JETFB+LPGB+GSLNB+KERB+GSOILB+FOILB+NGB+ELECB+SOLIDB

Petroleum product demand by the power sector in million BOE

GSOILEB = (GSOILE * 6.189) / 1000
FOILEB = (FOILE * 6.502) / 1000

Total energy demand in million BOE

TPPC = (JETFB+LPGB+GSLNB+KERB+GSOILB+FOILB) + (FOILEB+GSOILEB)

Domestic oil demand

DOILD = ((TPPC) * 1.14)

Total demand for natural gas

NGT = (NG + NGE + NGR) * 1.0496
NGR = 0.87 * (DOILD / 365)

Total primary energy demand in million BOE

NGTB = NGT * 6.388
SOLIDB = 1.01 * SOLIDB(-1)
HEGB = HEG * 630.38 / 1000000

TPED = DOILD + NGTB + SOLIDB + HEGB

Real prices of energy carriers

RPJETF = PJETF / CPI * 100
RPLPG = PLPG / CPI * 100
RPGSLN = PGSLN / CPI * 100
RPGSOIL = PGSOIL / CPI * 100
RPKER = PKER / CPI * 100
RPFOIL = PFOIL / CPI * 100
RPNG = PNG / CPI * 100
RPELEC = PELEC / CPI * 100

Prices of energy carriers per BOE

PJETFB = (PJETF * 1000) / 6.063
PLPGB = (PLPG * 1000) / 4.166
PGSLNB = (PGSLN * 1000) / 5.525
PKERB = (PKER * 1000) / 5.928
PGSOILB = (PGSOIL * 1000) / 6.189
PFOILB = (PFOIL * 1000) / 6.502
PNGB = (PNG * 1000) / 6.388
PELECB = (PELEC * 1000000) / 630.38

Average price of energy

PENG = [(PJETFB * JETFB) + (PLPGB * LPGB) + (PGSLNB * GSLNB)
+ (PKERB * KERB) + (PGSOILB * GSOILB) + (PFOILB * FOILB)
+ (PNGB * NGB) + (PELECB * ELECB)] / (TFEDB - SOLIDB)

IMPLICIT SUBSIDY MODEL (in billion US$)

SJETF = ((PBJETF - (PJETF / ER)) * JETF) / 1000
SLPG = ((PBLPG - (PLPG / ER)) * LPG) / 1000
SGSLN = ((PBGSLN - (PGSLN / ER)) * GSLN) / 1000
SGSOIL = ((PBGSOIL - (PGSOIL / ER)) * GSOIL) / 1000
SKER = ((PBKER - (PKER / ER)) * KER) / 1000

SFOIL = ((PBFOIL - (PFOIL / ER)) * FOIL) / 1000
SNG = (PBNG - (PNG / ER)) * NG
SELEC = ((PBELEC - (PELEC / ER)) * ELEC) / 1000

SUBSID = SJETF + SLPG + SGSLN + SGSOIL + SKER + SFOIL + SNG + SELEC

Appendix B: List of Variables

Name	Definition	Unit	Source
AERC	Average conversion rate to convert the dollar value of export into Rial in constant prices	Rial per US$	Own calculation
BE	Buyback expenditure	Billion US$	National Iranian Oil Company (NIOC)
CAPIM$	Dollar value of capital goods import	Million US$	Central Bank of Iran
CO*j*	Amount of energy *j* conserved. *j*={JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC}.	Million BOE	Own calculations
Cp	Consumption expenditure in constant 1982 market prices	Billion Rial	Central Bank of Iran
CPI	Consumer price index	1982 =100	Central Bank of Iran
DGDE	Dummy variable, 1 for 1994-1996 and 0 otherwise.	Unit free	
DSGLN	Dummy variable for the period gasoline was rationed. 1 in 1980-1982 and 0 otherwise.	Unit free	
DGSOILE	Dummy variable for natural gas and gas oil substitution in power generations; 1 for 1989-1998 and 0 otherwise.	Unit free	
DOILD	Domestic oil demand	Million barrels	NIOC
EGCO	Electricity conservation due to fuel use reduction	Million barrels	Own calculations
ELEC	Electricity final demand	Million kWh	Ministry of Energy
ER	Exchange rate in free market	Rial per US$	Central Bank of Iran
ETCO	Electricity conservation due loss reduction	Million barrels	Own calculations
FDI	Foreign direct investment	billion US$	Central Bank of Iran
FOIL	Fuel oil final demand	Million liter	National Iranain Oil Refinery & Distribution (NIORDC)
FOILE	Fuel oil demand power sector	Unit	Ministry of Energy
G	Government expenditure in 1982 market prices	Billion Rial	Central Bank of Iran
GDEM82	Gross domestic expenditure in 1982 market prices.	Billion Rial	Central Bank of Iran
GDPM82	Gross domestic product in 1982 market prices	Billion Rial	Central Bank of Iran
GEG	Gross electricity generated	Million kWh	Ministry of Energy
GSLN	Gasoline final demand	Million liter	NIORDC
GSOIL	Gas oil final demand	Million liter	NIORDC
GSOILE	Gas oil demand by the power sector	Million liter	Ministry of Energy
HEG	Hydro electricity generated	Million kWh	Ministry of Energy
I	Investment in 1982 market prices	Billion Rial	Central Bank of Iran
jB	Mostly denotes an energy variable in barrel	BOE	
JETF	Jet fuel final demand	Million liter	NIORDC
KER	Kerosene final demand	Million liter	NIORDC
LIQUID	Liquidity	Billion Rial	Central Bank of Iran
LOADA	Aviation carried cargo	1000 tone/kilometer	Iran Statistical Center (ISC)
LPG	Liquefied Petroleum Gas final demand	Million liter	NIORDC
M	Import in 1982 market prices	Billion Rial	Central Bank of Iran
NELECC	Number of electricity users	1000 customers	Ministry of Energy
NG	Natural gas final demand	Billion m^3	National Iranian Gas Company
NGE	Natural gas demand power sector	Billion m^3	Ministry of Energy
NGR	Natural gas demand in Refineries	Billion m^3	NIORDC
NGT	Natural gas demand total	Billion m^3	Own calculation
NOILR$	Dollar value of non-oil export (Nominal)	Billion US$	Central Bank of Iran

NHOUS	Number of households	Actual number	ISC
NRHOUS	Number of Rural Households	Actual number	ISC
OILR$	Oil revenue	Billion Rial	Central Bank of Iran
OILR$	Dollar value of oil export (Nominal)	Billion US$	Central Bank of Iran
OILRES	Oil reserves	Billion barrel	BP
PASA	Aviation carried passengers	Million passenger per kilometer	ISC
PENG	Nominal price of energy (weighted average)	Rial/BOE	Own calculation
Pj	Nominal price of fuel j per unit; j = JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC.	Rial per unit	Ministry of Energy
PjB	Nominal price per barrel of fuel j; j = JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC.	Rial/BOE	Own calculation
POIL	Oil price(average price of Iran's oil)	US$ per barrel	OPEC Annual Statistical Bulletin
POP	Population	Head	ISC
QOIL	Domestic oil production	Million barrels per day	Institute for International Energy Studies (IIES), Petroleum Development & Engineering Company (PDEC
R$	Dollar value of oil and non-oil export or Dollar inflow	Billion US$	Central Bank of Iran
RPj	Real price of fuel j per unit; j = JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC.	Rial per unit	Own calculations
QTEG	Quantity of Thermal Electricity Generation	Million kWh	Ministry of Energy
SGSCAR	Stock of gasoline using cars	Actual number	ISC
SGOCAR	Stock of gas oil using cars	Actual number	ISC
SH	Share of hydro electricity in total electricity generation	Percentage	Ministry of Energy
SOLIDB	Solid fuels	Million BOE	Ministry of Energy
Sj	Implicit subsidy on final demand fuel j; j = JETF, LPG, GSLN, KER, GSOIL, FOIL, NG, ELEC.	Billion US$	Own calculations
SUBSID	Total implicit subsidies on final energy demand	Billion US$	Own calculations
TFEDB	Total final energy demand	Million barrels	Own calculations
TFCO	Total final energy conservation	Million barrels	Own calculations
TPED	Total primary energy demand	Million barrels	Own calculations
TPPC	Total petroleum product consumption	Million barrels BOE	Own calculations
TREND	Time trend with 1974 = 1	Unit free	
X	Export in 1982 market prices	Billion Rial	Central Bank of Iran
XOIL	Oil export	Million barrels per day	OPEC Annual Statistical Bulletin

Nederlandse Samenvatting

De Islamitische Republiek Iran beschikt over aanzienlijke voorraden van de natuurlijke hulpbronnen aardolie en aardgas. In het jaar 2000 was dit een kleine 10% van de aangetoonde wereld olievoorraad en zo'n 16% van de aardgasvoorraad. Hiermee was Iran nummer vier op het gebied van olie en na de Russische Federatie nummer 2 als het gaat om aardgas. Voor de meeste Iraniërs is het idee dat er in de toekomst wellicht te weinig olie beschikbaar is voor export dan ook ondenkbaar. Toch dreigt deze situatie op de niet al te lange termijn te ontstaan indien het binnenlandse verbruik van olieproducten een gelijke groei blijft vertonen als in het verleden. Deze groei bedroeg over de periode 1974-1998 gemiddeld een kleine 5.6% per jaar. In termen van consumptie betekent dit dat de binnenlandse consumptie is opgelopen van 0.32 miljoen vaten per dag in 1974 tot 1.21 miljoen in 1998. De productiecapaciteit voor olie bedroeg in 1998 echter slechts 3.84 miljoen vaten per dag, tegenover 6 miljoen in 1974, en de feitelijke productie 3.73 miljoen. Bij een gelijke groei in de vraag en een verdergaande afname van de productiecapaciteit zal rond 2020 de binnenlandse vraag groter zijn dan de productiecapaciteit.

De stijging in binnenlands verbruik van olieproducten hoeft geen probleem te zijn indien deze stijging werd veroorzaakt door een groei van het reële bruto binnenlands product (BBP). De gemiddelde groei van het BBP in constante prijzen van 1982 over dezelfde periode bedroeg echter slechts een kleine 1.9% per jaar. Met andere woorden, de groei van het binnenlands verbruik van olieproducten in Iran was bijna een factor drie groter dan de groei van de economie in termen van reëel BBP.

Het gevolg van de afnemende productiecapaciteit en de stijgende binnenlandse consumptie van olie, in combinatie met de lage economische groei, zorgt ervoor dat de olie-inkomsten, de belangrijkste bron van export inkomsten voor Iran, onder druk staan.

Er zijn een aantal oorzaken aan te wijzen voor de sterke stijging in het binnenlands verbruik van olieproducten, zoals de afwezigheid van adequate regulering op het gebied van energieverbruik en een zeer inefficiënte elektriciteit en raffinage sector. Daarnaast spelen demografische factoren, zoals de sterke groei van de bevolking en de trek naar de steden, een rol. De belangrijkste oorzaak vormen echter de extreem lage nominale en reële prijzen van energieproducten. Zo is de prijs van benzine in Iran, op één na, de laagste in de wereld. De prijs van benzine in het jaar 2000 was ongeveer 25% van de prijs op de internationale markt. Voor diesel, stookolie en LPG bedroeg dit percentage in het jaar 2000 respectievelijk 7,0%, 5,4% en 8,4%. Deze extreem lage prijzen hebben geleid tot de sterke groei in verbruik.

Een manier om de economische kosten van deze prijspolitiek uit te drukken is het berekenen van de impliciete subsidies op energie. De subsidie in een bepaald jaar op bijvoorbeeld benzine kan worden geschat door het binnenlands verbruik van benzine te vermenigvuldigen met het verschil tussen de prijs op de internationale markt en de binnenlandse prijs. Voor de verschillende energieproducten staan deze impliciete subsidies weergegeven in tabel 1. Omdat de prijs van olie op de internationale markt sterk fluctueert, tonen ook de impliciete subsidies sterke fluctuaties. Zo bedroeg de gemiddelde prijs van een vat olie in 1996 zo'n 20 US$ gedaald, maar in 1998 slechts 10.8 US$.

Tabel 1: Impliciete subsidies op energie in miljarden US$

Jaar	Jet fuel	LPG	Benzine	Kerosine	Diesel	Stook-olie	Aardgas	Elektri-citeit	Totaal
1994	0.10	0.40	1.31	1.43	2.74	0.97	1.64	3.55	12.15
1995	0.11	0.42	1.22	1.45	2.71	0.91	2.01	3.79	12.61
1996	0.15	0.54	1.46	1.91	3.54	1.07	2.72	4.44	15.83
1997	0.15	0.48	1.54	1.58	3.22	1.08	2.51	4.15	14.70
1998	0.09	0.31	0.91	0.95	2.04	0.64	1.88	2.60	9.29
1999	0.13	0.46	1.28	1.23	2.68	0.66	1.31	3.42	11.17
2000	0.19	0.68	2.03	1.78	3.79	0.88	1.39	3.64	14.38

De "internationale" prijzen van aardgas en elektriciteit zijn vastgesteld op basis van respectievelijk aardgascontracten met buurlanden en de kosten van elektriciteitsproductie in Turkije. De totale waarde van de impliciete subsidies liggen tussen de 10% en 15% van het BBP in constante prijzen en zijn van dezelfde orde van grote als de bijdrage van de oliesector aan het BBP.

De centrale vraag die in dit proefschrift wordt bestudeerd is dan ook:

Welke zijn de zwakke en sterke punten van de binnenlandse energiesector in Iran, welke kansen en bedreigingen kent deze, en welke energiepolitiek kan ervoor zorgen *dat de binnenlandse energiesector een positieve bijdrage levert aan de Iraanse economie?*

Om deze vraag te kunnen beantwoorden zijn in hoofdstuk 2 allereerst de zwakke en sterke punten van de Iraanse economie in z'n algemeenheid en die van de binnenlandse energiesector in het bijzonder in kaart gebracht. Daarnaast is gekeken naar de kansen en bedreigingen. Naast het bovengenoemde prijsbeleid is de moeizame besluitvorming als het gaat om de binnenlandse energiesector en belangrijk zwak punt. De sector wordt volledig gedomineerd door de overheid en de besturing ervan wordt in grote mate door de regering gedaan.

In hoofdstuk 3 is de externe omgeving in kaart gebracht. Aangetoond is dat de internationale markt voor energie, en voor olieproducten in het bijzonder, de komende vijftig jaar blijft groeien. Het vraagniveau zal naar verwachting in de OECD landen, o.a. om milieupolitieke redenen en een verzadiging van de markt, stabiliseren of wellicht op termijn zelfs iets afnemen. Dit effect zal echter ruimschoots teniet worden gedaan door de stijgende vraag in ontwikkelingslanden. De inkomensgroei in landen als China en India zal leiden tot een groei in de vraag naar olieproducten. Ook het effect van nieuwe technologieën zal naar verwachting de komende vijftig jaar niet zodanig zijn dat dit leidt tot een absolute afname van de vraag naar olie.

Op basis van de analyses in de hoofdstukken 2 en 3 wordt in hoofdstuk 4 een SWOT analyse van de binnenlandse energiesector van Iran gemaakt, waarbij SWOT staat voor Strengths, Weaknesses, Opportunities en Threats. Deze in Harvard ontwikkelde methode wordt normaal toegepast op bedrijven; hier is de methode echter aangepast en toegepast voor een sector. Het resultaat van de SWOT analyse is de formulering van effectieve strategieën voor de toekomst.

De SWOT analyse van de binnenlandse energiesector heeft aangetoond dat er drie hoofdstrategieën zijn die moeten worden uitgewerkt:

1. Het vervangen van olie door aardgas. Omdat Iran beschikt over grote hoeveelheden goedkoop aardgas en aardgas om technische redenen veel moeilijker kan worden geëxporteerd dan olie, ligt het voor de hand het binnenlands gebruik van olie terug te dringen via het gebruik van aardgas. Deze strategie wordt reeds enige tijd toegepast.
2. Het ontwikkelen van een energiebesparingsbeleid. De kern van dit beleid moet worden gevormd door het verwijderen de impliciete subsidies op energie. Echter

een aangepast prijsbeleid alleen is onvoldoende. Dit beleid moet worden ondersteund door additionele maatregelen ter bevordering van de energiebesparingen.

3. Het besluitvormingsproces voor de binnenlandse energiesector moet worden verbeterd. Nagenoeg alle bedrijven in de energiesector zijn eigendom van de overheid en de overheid heeft een sterke invloed op de dagelijkse leiding ervan. Voor een groot aantal bedrijven zou liberalisering, en eventueel privatisering, moeten worden overwogen.

In het vervolg van het proefschrift is getracht de eerste twee strategieën te kwantificeren, waarbij de nadruk heeft gelegen op de tweede strategie. Het verbeteren van de efficiëntie en de effectiviteit van de besluitvorming, de derde strategie, is weliswaar essentieel voor de eerste twee, maar vraagt om een ander type analyse dan de eerste twee.

De nadruk bij de eerste twee strategieën ligt op de tweede, omdat het vervangen van olie door gas in de binnenlandse energievoorziening al enige tijd wordt geïmplementeerd. De discussie over de tweede strategie, energiebesparing door o.a. de invoering van een adequaat prijsbeleid, is daarentegen nog nauwelijks gevoerd. Hiervoor zijn zowel politieke als economisch redenen. Politiek is het moeilijk te verkopen dat de prijzen van energieproducten aanzienlijk moeten stijgen. De jaarlijkse inflatie is rond de 20% en de loonstijgingen blijven hierbij sterk achter. De verwachting is dat het algemeen prijspeil door een fikse verhoging van de energieprijzen alleen nog maar zal toenemen. Echter de belangrijkste oorzaak van de grote inflatie is de sterke stijging van de geldhoeveelheid als gevolg van de inflatoire financiering van z'n uitgaven door de overheid.

De vraag is nu of de inflatie niet sterk kan worden teruggedrongen door de afschaffing van de impliciete subsidies op energieproducten. Verwijdering van de impliciete subsidies leidt tot prijsstijgingen van tussen de 400% voor benzine tot een kleine 1850% voor stookolie. Dit zijn weliswaar forse prijsstijgingen, maar ook na een dergelijke operatie zijn de energieprijzen in Iran nog steeds aanmerkelijk lager dan in de meeste andere landen van de wereld. De verwachting is dat de prijsstijgingen zullen leiden tot een aanmerkelijke verlaging van het binnenlands energieverbruik. De prijsstijgingen zullen in eerste instantie inderdaad een grotere inflatie tot gevolg hebben. Echter door de extra inkomsten voor de overheid uit enerzijds de verkopen van energie in het binnenland en anderzijds de verhoogde inkomsten uit de extra export van olie zal de noodzaak tot inflatoire financiering aanmerkelijk doen afnemen. Gevolg hiervan is dan weer dat, bij een goede implementatie van de maatregelen, de inflatie op de wat langere termijn sterk zal afnemen.

De prijsaanpassingen alleen zijn echter onvoldoende om een maximaal rendement uit deze politiek te halen. De prijspolitiek moet worden ingebed in een adequate regelgeving op het gebied van energieverbruik en energiebesparing. Het effect van de prijsmaatregel kan daar aanzienlijk door worden verstrekt.

Tezamen met een efficiëntere overheid is de prijspolitiek ook een noodzakelijke voorwaarde voor een succesvolle liberalisering, en mogelijk privatisering, van onderdelen van de binnenlandse energiesector. Immers alleen bij voldoende inkomsten uit eigen activiteiten kunnen bedrijven in de energiesector zelfstandig opereren.

Om na te gaan of en in welke mate deze effecten zullen optreden is een model gemaakt van het binnenlands energieverbruik in Iran. Dit model van de energiesector is gecompleteerd met een eenvoudig macromodel om de effecten van meer olie-inkomsten te kunnen evalueren. Dit model is te vinden in hoofdstuk 6. In dit hoofdstuk is ook het referentie of RF scenario ontwikkeld. Dit scenario geeft de ontwikkeling weer van de binnenlandse energiesector tot 2020 bij ongewijzigd beleid. De belangrijkste conclusies zijn:

- De finale vraag naar energie blijft groeien met gemiddeld 4.5% per jaar, maar door de sterkere nadruk op aardgas neemt de finale vraag naar olie slechts toe met 2.3% per jaar. Met een gemiddelde groei van het BBP in constante prijzen van 2.4% betekent dit dat de Iraanse economie steeds energie-intensiever wordt.
- Ook de vraag naar primaire energie blijft sterk groeien en loopt, uitgedrukt in vaten olie, op tot 5.48 miljoen vaten per dag in 2020, waarvan 3.35 miljoen vaten in de vorm van aardgas.
- Door de stijgende binnenlandse vraag en omdat de productiecapaciteit van olie verder afneemt, loopt de export van olie in het RF scenario terug van 2.52 miljoen vaten per dag nu naar 1.33 miljoen in 2020.

- De impliciete subsidies op energie lopen op van US$ 9.35 miljard in 2000 naar US$ 20.6 miljard in 2020.

Het RF scenario is minder negatief dan een eenvoudige extrapolatie omdat het al rekening houdt met enige verbeteringen. Zo is de aanname over de gemiddelde stijging in liquiditeiten op 15% per jaar gezet terwijl deze in het verleden meer dan 20% bedroeg.

In hoofdstuk 7 wordt geanalyseerd wat het effect is van het verwijderen van de impliciete subsidies op energie, d.w.z. een aanpassing van het binnenlands prijsniveau aan dat van de internationale vrije marktprijzen. Deze aanpassing gebeurt over een periode van vijf jaar van 2002 tot 2007. Tegelijkertijd wordt de inflatoire financiering van het overheidsbudget teruggebracht om in 2007 uit te komen op 5% per jaar i.p.v. van 15%. Dit scenario wordt aangeduid als het RS (remove subsidy) scenario. Deze politiek heeft in de periode 2001-2007 de volgende effecten:

- De vraag naar energie neemt sterk af en groeit gemiddeld met slechts 1.2%, i.p.v. met bijna 4.5%. De bespaarde hoeveelheid energie over de periode 2002-2006 is equivalent aan 543.2 miljoen vaten olie, met een geschatte waarde van US$ 13 miljard.
- De binnenlandse vraag naar olie neemt af met gemiddeld 2.4% en is in het RS scenario in 2007 1.1 miljoen vaten per dag -tegenover 1.5 miljoen in het RF scenario-, hetgeen gelijk is aan het niveau van 1992.
- Het lagere binnenlandse verbruik impliceert een hogere export van olie. De export inkomsten nemen in het RS scenario dan ook toe van US$ 21 miljard in 2001 naar US$ 24 miljard in 2007, i.p.v. een afname zoals in het RF scenario.
- De prijsindex van consumptie goederen stijgt in 2003 en 2004 sneller dan in het RF scenario, maar na 2005 heeft het effect van de lagere groei in liquiditeiten de overhand en daalt de index in het RS scenario om in 2007 uit te komen op ongeveer het niveau van 2001. De wisselkoers vertoont een vergelijkbare ontwikkeling.

Ook voor de periode 2007-2020 heeft de nieuwe prijspolitiek duidelijke voordelen.

- De groei van het BBP is in het RS scenario gemiddeld 0.63% hoger dan in het RF scenario.

- De gemiddelde inflatie in het RS scenario voor de periode 2007-2020 is slechts 3.8%, tegenover 14.4% in het RF scenario. De wisselkoers vertoont een vergelijkbaar beeld.
- De binnenlandse vraag naar olie groeit met slechts 1.5% en bedraagt 1.33 miljoen vaten per dag in 2020 tegenover 2.02 miljoen in het RF scenario.
- De inkomsten uit de export van olie nemen sterk toe en bedragen in 2020 US$ 19.6 miljard, US$ 7 miljard hoger dan bij het RF scenario.
- De totale binnenlandse energiebesparingen uitgedrukt in vaten olie equivalenten bedragen 4.2 miljard. In termen van internationale prijzen is de waarde hiervan US$ 121.6 miljard. Dit bedrag is gelijk aan 51% van de totale olie-inkomsten in het RF scenario.
- De energie intensiteit neemt in het RS scenario af tot minder dan 73% van die in het RF scenario.

In tabel 2 zijn de resultaten voor beide periodes gecombineerd en worden beide scenario's vergeleken.

Tabel 2. Vergelijking van de twee scenario's voor de periode 2002-2020

Variabel	Waarde		Betere performance	Beschrijving
	RS	RF		
BBP	2.44%	1.73%	RS	per jaar
CPI	0.37%	14.07%	RS	per jaar
Reële energieprijzen	6.00%	-5.54%	RS	per jaar
Olie-inkomsten	423.3	335.0	RS	miljard US$
Wisselkoers	0.44%	13.72%	RS	per jaar
Energievraag	3.07%	4.23%	RS	per jaar
Energiebesparing	4.56	-	RS	miljard vaten
Energie-intensiteit	1.32%	2.87%	RS	per jaar
Impliciete subsidies	38.7	441.7	RS	miljard US$

Omdat de prijspolitiek effectiever zal zijn indien deze is ingebed in een groter pakket van energiebesparende maatregelen is nagegaan wat het effect van flankerende maatregelen kan zijn. Om een inschatting te kunnen maken is gekeken naar het effect van energiebesparingsmaatregelen in een drietal landen met een goede reputatie op het gebied van energiebeleid, te weten het Verenigd Koninkrijk, Nederland en Thailand. Voor deze drie landen is gekeken naar economisch haalbare besparingsscenario's. Daarnaast is voor Iran in kaart gebracht wat al onderzocht is als het gaat om energiebesparing. De resultaten voor de drie landen zijn weergegeven in de tabel 3.

Tabel 3. Het economisch haalbaar potentieel voor energiebesparing als percentage van de energieconsumptie in het basisjaar.

Land	Industrie	Woningen	Diensten	Transport	Landbouw	Total	Besparing
UK	38.0	30.0	24.0	69.0	-	-	in 2020 t.o.v. 1996
Nederland	28.5	44.0	59.9	28.2	76.0	41.0	in 2015 t.o.v. 1986 (TNO)
Nederland	35.0	64.0	65.0	45.0	73.0	49.0	in 2015 t.o.v. 1990 (ICARUS)
Nederland	17.0	10.0-30.0	-	-	-	-	in 2020 t.o.v. basis scenario (REDUCE)
Thailand	48.3	14.6	90.8	72.3	18.9	50.9	in 2025 t.o.v. 1998

Aan de gebruikte studies liggen meestal zeer gedetailleerde analyses van sectoren en technologieën ten grondslag. Ze kunnen dan ook niet meer dan een indicatie vormen voor de mogelijkheden in Iran. Verder worden de landen gekenmerkt door hoge energieprijzen die reeds enige tijd geleden zijn ingevoerd. Het Iraanse prijspeil blijft beneden dat van de bestudeerde landen, dit heeft een negatief effect op de potentiële besparing. Daar staat tegenover dat op het moment van de berekening van het besparingspotentieel de bestudeerde landen reeds enige tijd een beleid op het gebied van energiebesparing hadden ingevoerd en de snelle winsten reeds waren verwezenlijkt, dit in tegenstelling tot Iran waar nog geen binnenlands energiebesparingsbeleid is ingevoerd. Dit heeft een positief effect op de mogelijkheden voor energiebesparing in Iran t.o.v. de drie onderzochte landen. Tabel 4 bevat een overzicht van de belangrijkste instrumenten die in de verschillende landen worden ingezet en die ook voor Iran van belang zijn.

Op basis van de besparingsmogelijkheden in de bestudeerde landen en de informatie die bekend is over Iran, gaan we ervan uit dat de totale besparing die kan worden bereikt 32% van het finale verbruik in 2020 in het RF scenario bedraagt. Dit komt neer op een besparing van 40% van het totale finale energieverbruik in 2002. De extra besparingsmogelijkheden zijn toegerekend aan de diverse energiedragers op basis van de aandelen van de energiedragers in het finale verbruik in het RS scenario. We noemen dit scenario van additionele besparingen het IM scenario.

De belangrijkste effecten van de additionele maatregelen zijn:

- De finale vraag naar energie neemt af van 3.8 miljoen vaten per dag in 2020 in het RS scenario naar 3.1 miljoen in het IM scenario.
- De vraag naar olieproducten daalt naar 850.000 vaten per dag, het niveau van 1992.
- De additionele besparing in termen van vaten olie equivalenten op de finale vraag over de gehele periode in het IM scenario t.o.v. het RS scenario is 1.5 miljard vaten, en t.o.v. het RF scenario 4.6 miljard.
- De olie-inkomsten in 2020 bedragen US$ 22.4 miljard in het IM scenario tegenover US$ 19.6 in het RS scenario en US$ 13.0 in het RF scenario.
- Ook de groei van het BBP is in het IM scenario hoger, in 2020 zo'n 0.4% t.o.v. het RS scenario.

Tabel 4. Overzicht van energiebesparingsmaatregelen.

Omschrijving	VK	Nederland	Thailand
Energieagentschappen [1]	NR	NR	N
Nationaal energie efficiency programma	ja	Ja	ja
Energiebouwvoorschriften	verplicht	verplicht en gecontroleerd	verplicht en gecertificeerd
Labels en energie efficiency standaarden	verplicht en gecontroleerd	verplicht en gecontroleerd	verplicht
Fiscale maatregelenvoor auto's [2]	PT, RT	PT, RT	
Subsidies en incentives voor schone en efficiënte auto's [3]	EC, CC	EC	Conservation projects
Belasting op brandstoffen [4]	A, 0.91, 0.73	A, 0.71, 0.73	A, 0.13, 0.09
Energie audits[5]		D, C	D, C, G

1. N, R en L staan respectievelijk voor nationale, regionale en lokale agentschappen.
2. PT en RT staan respectievelijk voor "purchase tax" and "registration tax".
3. EC en CC staand voor respectievelijk elektrische auto en CNG auto.
4. A geeft aan dat op alle energiedragers belasting wordt geheven; het eerste getal is de belasting als fractie van de prijs voor benzine en het tweede getal voor diesel.
5. D, C en G staan voor respectievelijk huizen, bedrijven en overheidsgebouwen.

Uit de uitgevoerde analyses kunnen de volgende conclusies worden getrokken. De angst die bij veel Iraniërs leeft dat een aanpassing van de binnenlandse energieprijzen leidt tot inflatie en een verslechterende economie is ongegrond. Op de korte termijn zullen de prijsstijgingen voor energieproducten inderdaad leiden tot een verhoogde inflatie. Echter, indien de prijspolitiek wordt gecombineerd met een verbeterde geldpolitiek hebben de prijsstijgingen een blijvend positief effect op de Iraanse economie en zullen reeds na een drietal jaren de negatieve effecten van de prijsstijgingen teniet worden gedaan door de positieve effecten ervan. De politiek wordt dan gekenmerkt door een hogere economische groei, een aanmerkelijk lagere inflatie, een blijvende verbetering van de wisselkoers en een veel langere periode waarin olie-inkomsten een bijdrage kunnen leveren aan opbouw van de economie.

Indien het nieuwe prijsbeleid wordt ingebed in een pakket van energiebesparingsmaatregelen zoals deze ook in andere landen zijn ingevoerd kan het positieve effect van de prijsmaatregel zelfs aanzienlijk worden versterkt.

Uiteraard zijn deze conclusies tentatief. Hoe de nieuwe geldpolitiek precies moet worden uitgevoerd is in deze studie niet onderzocht. Ook is niet nagegaan hoe de minder draagkrachtigen voor de prijsstijgingen kunnen worden gecompenseerd. Hiervoor zijn additionele studies nodig.

Ook is onduidelijk hoe de besluitvorming over de binnenlandse energiepolitiek kan worden verbeterd. Liberalisering, en wellicht privatisering, van (grote) delen van de NIOC (de National Iranian Oil Company), die nu feitelijk door de overheid wordt bestuurd, zijn nodig om de veerkracht en winstgevendheid van de Iraanse binnenlandse energiesector te verbeteren. Hetzelfde geldt voor de elektriciteitssector en voor raffinaderijen. Maatregelen die zonder een aangepast prijsbeleid niet kunnen worden doorgevoerd omdat de inkomsten van de zelfstandige onderdelen onvoldoende zullen zijn om de benodigde energie-infrastructuur te garanderen. Ook zal de politiek zich moeten beperken tot het aangeven van de kaders voor de energiesector i.p.v. het besturen ervan. Op al deze gebieden is nog veel additioneel onderzoek nodig. Het is nu echter duidelijk dat een aangepaste energiepolitiek, met als kern hogere energieprijzen, een sterke positieve bijdrage kan leveren aan het economisch herstel van Iran.

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He is currently following another Master degree in Energy Engineering at Azad University In Tehran.

Mr. Moghaddam has worked and hold different positions for more than 25 years in various fields in National Iranian Oil Company (NIOC) and its related industries. He began as a Field Manager of Exploration and Production Division in 1978 and then joined Tehran Refinery in Process Engineering. Four years later he restructured the Iranian Petroleum Institute (1982). He was appointed as President of Scientific and Research Center of Ministry of Petroleum in 1984. Two years later he was elected as member of Board of NIOC and research training director in Research Deputy of Petroleum Ministery (1986). Later he became the Manager of oil and gas at Planning and Buget Organization. Meanwhile, he served as an advisor to Minister of Petroleum and Minister of heavy Industries in 1991. He worked on many projects especially in Oil Industry while he was in this position.

In 1994 he joined Institute for International Enery Studies (IIES) as research deputy. He became the General Director of the Organization and Method (O & M) of Ministry of Petroleum and NIOC one year later (1995). At this position he supervized many studies of different aspects of development In NIOC , which many of them has been implemented successfully , resulted in publication of more than 100 assessment work reports and scientific proposals. The first phase of fuel optimization research plan and gas master plan are among these studies. During his working carrier he also was incharge of restructuring the ministry of petroleum and affilated companies toward commercialization and privatization. At present Mr. Moghaddam is a member of the Board and Director of Corporate Planning of NIOC.